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THE EFFECTS OF MANAGEMENT INITIATIVES ON THE COSTS AND SCHEDULES OF DEFENSE ACQUISITION PROGRAMS

Volume II: Analyses of Ground Combat and Ship Programs

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November 1992

Prepared for
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INSTITUTE FOR DEFENSE ANALYSES
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This two-volume paper examines trends in the outcomes (in terms of costs and schedules) of the acquisition programs for major weapon systems, and assesses the effectiveness of management initiatives in improving these outcomes. IDA analyzed a total of 116 major programs that included a mix of aircraft, tactical munitions, electronics/avionics, strategic missiles, satellites, vehicles, and ships. In Volume I of the paper, program outcomes are assessed by equipment type, by time period, by phase (development and production), and by type (new or modification). The initiatives assessed are prototyping, contract incentives, multi-year procurement, design-to-cost, dual-source competition, and total package procurement and fixed-price development. Volume II contains special analyses of ships and ground combat programs. The management initiatives that show the most promise for containing cost and schedule growth are prototyping, contract incentives, and multi-year procurement.

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PREFACE

This document was prepared by the Institute for Defense Analyses (IDA) for the Office of the Under Secretary of Defense (Acquisition), Tactical Systems, under contract MDA 903 89 C 0003, Task Order T-F7-799, issued 15 March 1990, and amendment. The objective of the task was: (1) to add ground combat and ship programs to the existing IDA database of defense acquisition program data and (2) to analyze the effects of applying management initiatives on the costs and schedules of those programs. This is the second of two volumes reporting on the results of that task. Volume I assesses the patterns of cost and schedule growth and the effectiveness of management initiatives for all programs in the database. This volume presents the analyses of the ground combat and ship programs that were added to the database.

This work was reviewed within IDA by Stanley A. Horowitz, Barbara A. Bicksler, and An-Jen Tai.

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I. INTRODUCTION TO VOLUME II

The second volume of this report highlights the special features of the ground combat and ship programs selected for this study. The previous IDA report on this subject [1] included some of the programs discussed here, particularly the tactical munitions. Most of the programs, however, are new to our analysis.

Ground combat programs (Chapter II) include military vehicles and a set of distinctive Army programs. On average, the total program cost growth for ground combat programs is substantially higher than for other equipment types, while development cost growth and development schedule growth are among the highest. The Roland, which was canceled, has the highest total program cost growth, 319 percent. The MLRS program actually displayed negative cost growth. The Bradley Fighting Vehicle System has the highest development cost growth, 216 percent, due to problems inherited from the Mechanized Infantry Combat Vehicle (MICV) program. Development schedule growth for ground combat programs is high, 50 percent on average.

We examined whether management initiatives result in more favorable outcomes for ground combat programs. We found that, when we exclude the two programs that did not have any substantial production, there are no statistically significant correlations between the initiatives and the outcome measures. There are, however, some interesting relationships. For example, production cost growth averaged 8 percent for the MLRS and the M198 howitzer, which had multi-year contracts, while average PCG was 139 percent for programs without multi-year contracts.

The use of accelerated acquisition strategies in ground combat programs frequently led to unfavorable cost and schedule outcomes. In addition, these practices contributed to performance problems. In several cases, the system had to be abandoned or modified. Other factors that may have contributed to problems in ground combat programs are lack of industry capacity and lack of subsystem commonality.

The Navy ships and related acquisition programs (Chapter III) comprise three combat data systems, ten classes of surface vessels, and two classes of attack submarines. Total program cost growth (18 percent, on average) is considerably less for ships and related programs, when compared with the other equipment types. The average of 23

percent development cost growth is also less than for other equipment types. Development schedule growth averages only 17 percent—apparently, ship programs had a good record in reaching initial operational capability when planned.

The major initiatives had some significant impact on program outcomes. Total package procurement is related to higher production cost growth and total program cost growth. Prototyping is related to higher development cost growth, contrary to expectations. Incentive contracts in FSD are related to lower development cost growth.

It is surprising that we do not see a statistically significant effect of dual-sourcing, a major Navy initiative. However, we have only two programs with production data that were not dual-sourced, and their production cost growth is higher than the dual-sourced programs.

Several features distinguish the ship acquisition programs from the other acquisition programs. The first is that there are generally low numbers of units produced with very high unit costs. The greatest quantity to be produced in any of the ship programs is 65.

The second feature is that development costs are a low proportion of total program costs. On average, development costs represent less than 5 percent of total cost. Much of what the rest of the defense industry refers to as development costs are included in Navy production costs, and production costs also include the costs of the combat systems with which the ship is equipped.

The third feature is ship programs have been pursued at a time of great overcapacity in the U.S. shipbuilding industry. As a result, there has been great pressure on shipyards to compete with lower prices.

The final distinguishing feature is the high cost of adapting equipment to operate in the marine environment. Protecting ships against corrosion from saltwater and sea air, and the pounding and shocks to the hull of a ship from normal operations, is very costly.

Each chapter discusses the distinctive features of the equipment type, and presents a set of case studies describing each program, its history, its cost and schedule growth, and the management acquisition strategies applied.

II. GROUND COMBAT PROGRAMS

We selected nine ground combat programs to include in our study: three surface-launched tactical munitions platforms, one surface-launched artill , three armored vehicles, one intelligence processing system platform, and one field illery. Six of the programs are new to the database; three were already included in the database from our previous study. The programs are listed in Table I-1. Information on these programs was obtained from various Selected Acquisition Reports (SARs) and from Reference [2].

Table II-1. Ground Combat Programs

Program	Type	New or Modification	Quantity	Producers
FAADS LOS-R (Avenger)	Surface-Launched Tactical Munition	New	1,207	Boeing Aerospace Co.
Sgt. York (DIVAD)	Surface-Launched Tactical Munition	New	64	Ford Aerospace and Comm Corp.
MLRS	Surface-Launched Tactical Munition	New	4,813	LTV Aerospace and Defense Company
Roland	Surface-Launched Tactical Munition	New	27	Hughes Aircraft Co. and Boeing Aerospace Co.
M1 Abrams Tank	Armored Vehicle	New	2,488	General Dynamics
Bradley FVS	Armored Vehicle	New	2,300	FMC Corp.
M60A2	Armored Vehicle	Mod	543	Chrysler Corp.
ASAS/ENSCE	Intelligence Processing System	Mod	N/A	Jet Propulsion Laboratory
M198 155mm Towed Howitzer	Field Artillery	New	584	Rock Island Arsenal

Notes: See the individual case studies or the list of abbreviations at the end of this volume for the meanings of abbreviations and acronyms. N/A means not applicable.

Five of the nine systems are still in production. The earliest program started full-scale development in 1970 and began production in 1976 (M198 155mm towed howitzer). Two armored vehicle programs, the M1 Abrams tank and the Bradley Fighting Vehicle System (FVS), started full-scale development in 1976, started production in 1979 and 1980, and are still in production. These two programs underwent two and three major modifications respectively after they were developed. For the purpose of our analysis, we cut off development and production cost and schedule at the original version to have a more accurate measure of cost growth.

We included two programs that were terminated due to cost and performance problems, Roland and Sgt. York (DIVAD). Median development time for ground combat programs is 85 months. The production time span has a median of 69 months, including the projected time for programs that are still in production. Ground combat programs' development and production start dates, the initial operational capability (IOC) and projected production end dates are shown in Table II-2.

Table II-2. Development and Production Times for Ground Combat Programs

Program	FSD Start	IOC	Dev. Time (in months)	Prod. Start	Prod. End	Prod. Time (in months)
FAADS LOS-R (Avenger)	Nov-86	Sep-89	34	Aug-87	Sep-97	121
Sgt. York (DIVAD)	Nov-77	Mar-87	112	May-82	Sep-85	40
MLRS	Jan-77	Mar-83	74	May-80	Sep-94	172
Roland	Jan-75	Jul-84	114	May-79	Sep-81	28
M1 Abrams Tank	Nov-76	Jan-81	50	Apr-79	Sep-83	53
Bradley FVS	Nov-76	Dec-83	85	Feb-80	Sep-84	55
M60A2	Mar-65	Sep-74	114	Mar-68	Sep-73	66
ASAS/ENSCE	Dec-84	Apr-89	52	Mar-87	Sep-06	234
M198, 155mm Towed Howitzer	Dec-70	Apr-79	100	Dec-76	Sep-82	69
Mean			82			97
Median			85			69
Low			34			28
High			114			234
Standard Deviation			31			69

As described in Section III of Volume I, we obtained information on development and production costs and schedules and IOC dates from the Selected Acquisition Reports (SARs) for each program. For systems that have multiple major modifications (e.g., Bradley FVS) or multiple subsystems [e.g., rocket and launcher for the Multiple-Launch Rocket System (MLRS)], the SAR does not have development cost nor production cost reported by modification version or by rocket and launcher. In these cases, we obtained the breakdown of production costs by version and subsystem from the Army Cost and Economic Analysis Center (CEAC). For surface-launched munitions systems (e.g., MLRS), price improvement curves for the current estimate of production cost at Development Estimate Quantity were developed by launcher, rocket, and practice rocket and added together to obtain the total production cost.

Cost growth is defined as the percentage by which actual cost exceeds estimated cost. (Negative growth is, of course, possible, if the actual turns out to be less than the estimate.) In development, actual cost is measured from the beginning of development to

the end of development of the first version of the system. In production, actual cost is adjusted for quantity change, by means of a price improvement curve.

Quantity growth is defined as the percentage by which actual quantity exceeds planned quantity, while schedule growth is defined as the percentage by which the actual schedule exceeds the planned schedule. The development schedule is defined as the number of months from Milestone II to IOC, while the production schedule is defined as the number of months from Milestone III to the end of the production run for the first version of the system.

Information on the acquisition program initiatives applied to each of the programs was obtained from the SARs and from questionnaires submitted to the Army program managers. The measures of effectiveness were then compared to determine the effectiveness of the acquisition program initiatives. Comparisons between the sample of programs to which a particular acquisition initiative was applied and the sample of programs to which the initiative was not applied were made. The course of our analyses and a brief case study of each of the programs are contained in the pages that follow.

A. ANALYSIS

In this section we describe our analyses of ground combat programs in four areas: distinguishing features, program outcomes, and effects of acquisition initiatives on program outcomes.

1. Distinguishing Features of Ground Combat Acquisition Programs

Current estimates of development, military construction, and production costs for each of the nine ground combat programs are shown in Table II-3. These estimates are based on data from the December 1989 SARs shown in the previous tables, converted to 1991 constant dollars.

Three features distinguish the ground combat acquisition programs from the other acquisition programs:

1. Larger numbers of units are generally produced relative to other types of weapon systems. The lowest quantity to be produced in the ground combat programs (excluding the two canceled programs) is 543.
2. The use of accelerated acquisition strategies in order to field the system as quickly as possible led to several practices: (a) concurrent development and production before operational and evaluation test completion (Sgt. York, Roland, M60A2), (b) procurement of nondevelopmental items (FAADS

Table II-3. Current Estimates of Ground Combat Program Costs (Millions of FY 1991 Dollars)

Program	Production Units	Development Cost	Development Estimate Quantity	Production Cost for Development Estimate Quantity	Military Construction Cost	Total Program Cost	Development Cost Percentage
FAADS LOS-R (Avenger)	1,207	14.4	1,207	1,141.7	0.0	1156.1	1.2%
Sgt. York (DIVAD)	64	413.0	618	14,205.6	48.8	14,667.4	2.8%
Roland	27	596.6	180	8,965.9	0.0	9,562.5	6.2%
MLRS	4,813	523.7	2,906	3,821.7	87.6	4,433.0	11.8%
M1 Abrams Tank	2,488	2,006.2	3,312	9,105.8	26.3	11,138.3	18.0%
Bradley FVS	2,300	960.1	1,190	2,764.0	46.2	3,770.3	25.5%
M60A2	543	72.0	600	2,006.5	0.0	2,078.5	3.5%
ASAS/ENSCE	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M198, 155mm Towed Howitzer	584	128.9	654	351.2	0.0	480.1	26.8%

Note: N/A means that data were either not available or insufficient.

LOS-R, ASAS/ENSCE), (c) procurement of a system with limited capability configuration (ASAS), (d) limited urgent procurement (ASAS). These practices contributed to high growth in cost, delays in schedules, reduction in performance levels (Roland), and acquisition of systems that could not meet performance requirements without major modifications (Sgt. York, M60A2, FAADS, ASAS/ENSCE).

3. On average, the ground combat acquisition programs have higher development schedule and development and production cost growth than other systems. Most of the ground combat acquisition programs examined here took place when military spending was in an upward trend. Perhaps the cost and schedule problems in this set of programs occurred because industry had to add capacity to meet demand. Another potential reason for the problems that occurred is the lack of commonality between ground combat program subsystems. Examples of this lack of commonality for the ground combat programs are shown in Table II-4.

2. Outcomes of Ground Combat Acquisition Programs

Measures of acquisition program outcomes for the ground combat programs are shown in Table II-5. These outcome measures are very different from the outcome measures for the other acquisition programs in the study. On average, the total program cost growth and production cost growth for the ground combat programs are substantially higher, while development cost growth is similar to the tactical munitions. For comparison, acquisition program outcome means of ground combat programs and other equipment programs are shown in Table II-6.

The Bradley FVS has the highest development cost growth of the ground combat programs. That is probably because that program inherited its engineering development and funding from the troublesome Mechanized Infantry Combat Vehicle (MICV) program, which was terminated after five years in development. The MICV problems included failure to meet system weight specifications (approximately 1,000 pounds heavier), and performance requirements, such as reliability and durability, which resulted in design changes, hence, high cost growth.

High average production cost growth is due to four programs, M60A2, Roland, Sgt. York, and Bradley FVS. M60A2 and Roland had performance problems and design changes, the cost effects of which were aggravated by concurrency in development and production. Both Sgt. York and Bradley failed to meet performance requirements, Sgt. York due to its accelerated acquisition strategy, and Bradley due to the addition of more advanced technology.

Table II-4. Commonality of Subsystems Between Ground Combat Programs

Subsystems	Type	Manufacturer	Avenger	Sgt York	MLRS	Roland	M1 Tank	Bradley	M60A2	ASAS/E	M198
M109 155mm SP howitzer	Chassis	GM Corp	—	—	—	X	—	—	—	—	—
8V-71T	Diesel engine	GM Detroit Diesel	—	—	—	X	—	—	—	—	—
XTG-411-2A	Transmission	GM Allison	—	—	—	X	—	—	—	—	—
AVDS 1790-2A	Engine	Teledyne Continental	—	—	—	—	—	—	X	—	—
Modified M48A5	Chassis	Ford Aerospace	—	X	—	—	—	—	—	—	—
AVDS-1790-2D	Diesel engine	Teledyne Continental	—	X	—	—	—	—	—	—	—
CD series 850-6A	Diesel engine	GMC, Allison	—	X	—	—	—	—	—	—	—
Stinger	Missile	General Dynamics	—	X	—	—	—	—	—	—	—
Twin 40mm L/70	Gun	AB Bofors of Sweden	—	X	—	—	—	—	—	—	—
XM723	Chassis	FMC Corp	—	—	X	—	—	X	—	—	—
VTA-903T	Diesel engine	Cummins	—	—	X	—	—	X	—	—	—
VT903T	Diesel engine	Cummins	—	—	—	—	—	X	—	—	—
M77	Munition warhead	Vought	—	—	—	—	—	—	—	—	—
HMPT-500	Transmission	General Electric	—	—	X	—	—	X	—	—	—
HMMPT-500-3	Gearbox	General Electric	—	—	—	—	—	X	—	—	—
BGM-71 TOW	Missile	Hughes	—	—	—	—	—	X	—	—	—
M242 Bushmaster 25mm	Gun	McDonnell Douglas	—	—	—	—	—	X	—	—	—
AN/VVS-2	Passive night scope	Baird Corp	—	—	—	—	—	X	—	—	—
AVDS-1790-2C	Diesel engine	Teledyne Continental	—	—	—	—	—	—	X	—	—
AGT-1500	Gas turbine engine	Lycoming Textron	—	—	—	—	X	—	—	—	—
Automatic	Transmission	GM Allison Trns. Div.	—	—	—	—	X	—	—	—	—
7.62mm M240	Machine gun	Belgium	—	—	—	—	X	—	—	—	—
12.7mm M2 HB	Machine gun	Browning	—	—	—	—	X	—	—	—	—
Shellelagh	Missile	—	—	—	—	—	—	—	X	—	—
152mm	Gun/launcher	—	—	—	—	—	—	—	X	—	—
XM50/XM51	Passive night periscopes	—	—	—	—	—	—	—	X	—	—
AMCTC 4256	Laser range finder	—	—	—	—	—	—	—	X	—	—
ASAS/ENSCE Interf Mod (AIM)	Hardware module	Martin Marietta	—	—	—	—	—	—	—	X	—
Intel Data Proc (IDP)	Hardware module	Martin Marietta	—	—	—	—	—	—	—	X	—
Fwd Sens Intf & Cont (FSIC)	Hardware module	Ford Aerospace	—	—	—	—	—	—	—	X	—
Com. Proc & Interface (CPI)	Hardware module	Ford Aerospace	—	—	—	—	—	—	—	X	—
Port ASAS Work Stat (PAWS)	Hardware module	Martin Marietta	—	—	—	—	—	—	—	X	—
A/E Intf Mod Bestfed (ABB)	Hardware module	JPL	—	—	—	—	—	—	—	X	—

Table II-5. Outcome Measures for Ground Combat Programs (Percent)

Program	Development Schedule Growth	Development Cost Growth	Production Cost Growth	Production Quantity Growth	Production Schedule Growth	Stretch	Total Program Cost Growth
FAADS LOS-R (Avenger)	0	5	N/A	N/A	N/A	N/A	N/A
Sgt. York (DIVAD)	15	29	216	-90	-51	371	203
MLRS	6	2	-12	66	72	4	-8
Roland	115	52	383	-85	-57	187	319
M1 Abrams Tank	-6	54	36	-25	-54	-39	40
Bradley FVS	23	216	259	93	0	-48	250
M60A2	217	28	121	-9	-10	-1	115
ASAS/ENSCE	49	49	N/A	N/A	N/A	N/A	N/A
M198, 155mm Towed Howitzer	30	35	29	-11	-9	2	31

Note: N/A means that data were either not available or insufficient.

Table II-6. Cost and Schedule Outcomes for Ground Combat Programs and Other Equipment Types

Program By Equipment Type	Development Time N	Development Time Avg. (mos.)	Production Time N	Production Time Avg. (mos.)	Development Schedule Growth N	Development Schedule Growth Avg. (%)	Production Schedule Growth N	Production Schedule Growth Avg. (%)	Development Cost Growth N	Development Cost Growth Avg. (%)	Production Cost Growth N	Production Cost Growth Avg. (%)	Total Program Cost Growth N	Total Program Cost Growth Avg. (%)
Ground Combat	9	82	9	97	9	50	7	-16	9	52	7	147	7	136
Ships and Related	14	90	10	166	13	17	10	53	13	23	10	17	10	18
Aircraft	27	72	23	135	27	14	23	70	27	33	25	27	25	27
Tactical Munitions	30	82	26	119	30	50	26	70	30	56	26	79	26	68
Other	19	92	13	119	21	41	11	48	21	55	14	60	14	42

Note: Some programs identified as tactical munitions in Volume I of this paper are considered to be ground combat programs in this volume; consequently, averages may vary.

Development schedule growth for ground combat programs is high, 50 percent. In specific cases, this high growth was due to concurrency of system development and production, system failure to meet performance requirements (e.g., M60A2 and Roland), and system design restructure during the development phase (e.g., M198 155mm howitzer). Mean production schedule growth is much lower. Lower production schedule growth is partly due to the cancellation of two programs out of nine in the sample (Roland and Sgt. York) after only three years in production. Also for the Bradley FVS and the M1 Abrams Tank, only original versions are considered for the analysis—that is the systems in production were modified to a new version before production reached the quantity planned. Production quantity growth is much lower for the same reason.

3. Effects of Acquisition Initiatives on Ground Combat Program Outcomes

Six acquisition initiatives have been applied to different ground combat programs in various combinations. These initiatives are:

- Prototyping—five programs;
- Competition—three programs in advanced development, four programs in full-scale development (FSD), no programs in production;
- Multi-year procurement (MYP)—two programs;
- Design-to-cost (DTC)—four programs;
- Contract incentives—one program in advanced development, four in FSD, and three in production; and
- Firm fixed-price development (FPD)—one program.

The total package procurement initiative was not applied to any ground combat program. Acquisition initiatives in ground combat programs are shown in Table II-7.

We examined Pearson correlation coefficients of the 1/0 variables representing the acquisition initiatives with the outcome measures. There are only two relationships of even borderline statistical significance: MYP is negatively correlated with PCG (significance level=.11) and TPCG (.09), and incentive contracting in production is positively correlated with PCG (.11) and TPCG (.10). In general, aside from MYP, initiatives found to be effective in other programs do not seem to have the same effect here. To some extent, this may be because of a small sample size and the unique problems of the ground combat programs. In addition, the variability of program outcomes is high. When we examine averages, one program such as Roland may skew the results. When we omit the two

Table II-7. Acquisition Initiatives Applied in Ground Combat Programs

		Competition						Contract Incentives		
Program	Prototype	Adv. Devel.	FSD	Production	MYP	DTC	FPD	Adv. Devel.	FSD	Production
Active Programs										
ASAS/ENSCE	X	—	—	—	—	—	—	—	—	—
Bradley FVS	X	X	—	—	—	X	—	—	X	—
FAADS LOS-R (Avenger)	—	X	X	—	—	—	—	—	—	—
M1 Tank	X	—	X	—	—	X	—	—	X	X
MLRS	X	X	X	—	X	X	—	X	X	—
Inactive Programs										
M60A2	—	—	—	—	—	—	—	—	—	—
M198 Howitzer	X	—	—	—	X	—	—	—	—	—
Roland	—	—	—	—	—	—	—	—	X	X
Sgt. York (DIVAD)	—	—	X	—	—	X	X	—	—	X

Note: Bradley FVS and the M1 tank programs used MYP for later versions. None of the ground combat programs used total package procurement or dual-sourcing in production.

programs that did not engage in any substantial production (Roland and Sgt. York), there are no significant correlations between the initiatives and the outcome measures.

Nevertheless, our small sample size allows us to look more closely at specific programs. While the relationships revealed by doing this are not statistically significant, they are often interesting.

a. Prototyping

Development cost growth in prototyped ground combat programs is higher than in non-prototyped programs. However, production cost growth is lower, an indication that prototyping has some beneficial effect (Figure II-1). The mechanism for this benefit appears to be the following: prototyping results in less development schedule growth (an average of 20 percent for prototyped vs. 48 percent for non-prototyped). Prototyped programs reach IOC closer to their planned times. We have seen that development schedule growth is a key driver of cost growth in production. This better adherence to schedule may help programs to avoid the trap of technical revision and stretchout that have plagued ground combat programs.

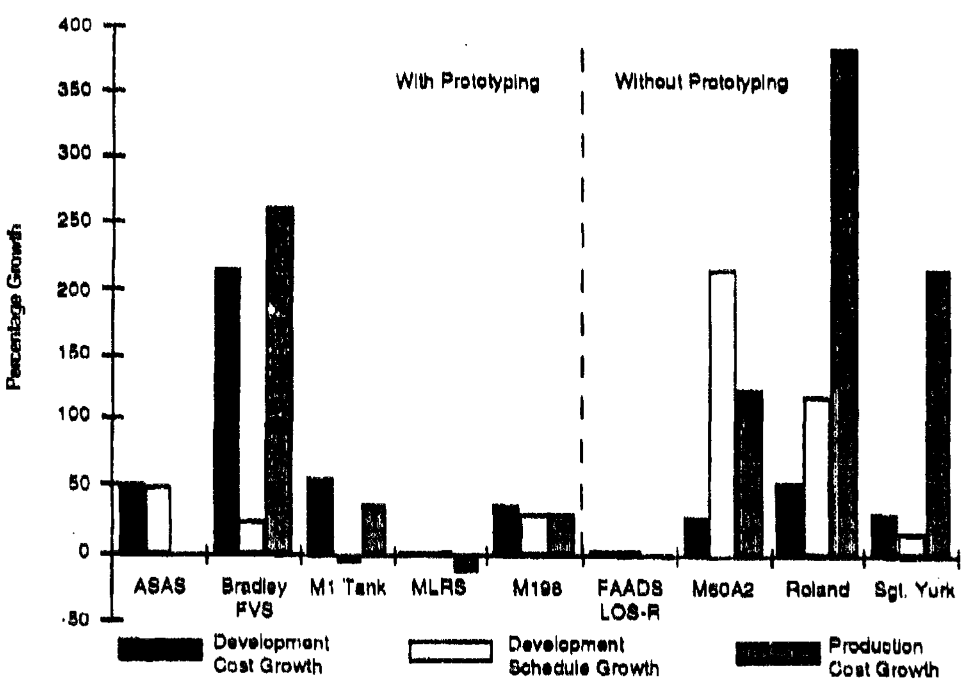


Figure II-1. Outcome Measures for Programs With and Without Prototyping

b. Competition

Dual-sourcing in production was not applied to any of the ground combat programs we are examining here. There are, however, four programs—the M1, FAADS LOS-R, MLRS, and the Sgt. York—that had more than one prime contractor involved in the full-scale development phase. Outcomes for these programs compare generally favorably with those that did not have competition in FSD (average total program cost growth of 16 percent vs. 132 percent), but the impact is not statistically significant (Figure II-2).

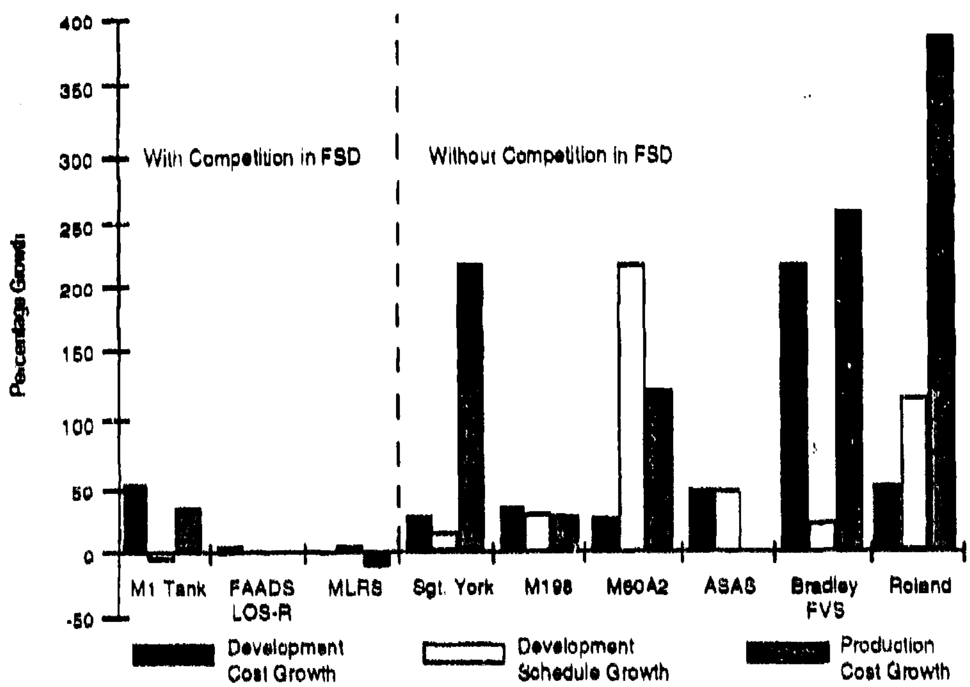
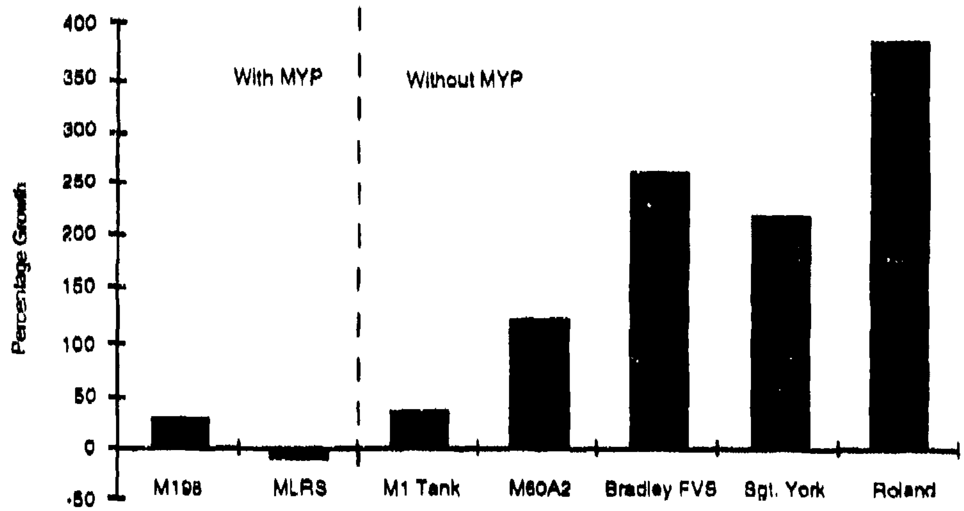


Figure II-2. Outcome Measures for Programs With and Without Competition in FSD

c. Multi-year Procurement

Only two ground combat programs in our study—MLRS and the M198 howitzer—used multi-year procurement (MYP). The Bradley and the M1 had multi-year contracts, but they were applied to later versions than the ones examined in this study. The two multi-year programs had considerably better production outcomes than the rest of the sample (Figure II-3). The average production cost growth was 8 percent for the two MYP programs vs. 139 percent for the other ground combat programs. As with other equipment

types, the multi-year commitment protected the programs from stretchout and thus prevented production cost growth.



Note: Production cost growth figures were not available for the ASAS/ENSCE or the FAADS LOS-R.

Figure II-3. Production Cost Growth for Programs With and Without Multi-Year Procurement

d. Design-to-Cost

For the design-to-cost (DTC) initiative, we have four ground combat programs with DTC (MLRS, Bradley FVS, Sgt. York, and M1 Abrams tank) and five without. DTC seems to affect production cost growth, although the relationship is not statistically significant. It has mixed results in controlling cost for the Army programs: successful for the MLRS and the M1, unsuccessful for the Bradley. For the MLRS, DTC was implemented in combination with other initiatives such as prototyping, competition in both advanced development and FSD, multi-year procurement, and contract incentives. For the M1 (original version), DTC was implemented in the program with prototyping, competition in FSD, and contract incentives in both FSD and production. DTC was claimed by both program offices to have been very effective in controlling cost and serving as a good design tool. For the Bradley (original version), DTC was applied with prototyping and competition in advanced development, but was dropped from the program as it progressed. According to the Army CEAC, this was due to the product improvement program. The Army kept improving the system with additional technologies, which led cost to rise higher than DTC goals. As improvements were incorporated, the Army did not

revise the DTC goals for the program. Moreover, note that even for the original version of the Bradley, DTC goals were not met. Outcomes of programs with and without DTC are shown in Figure II-4.

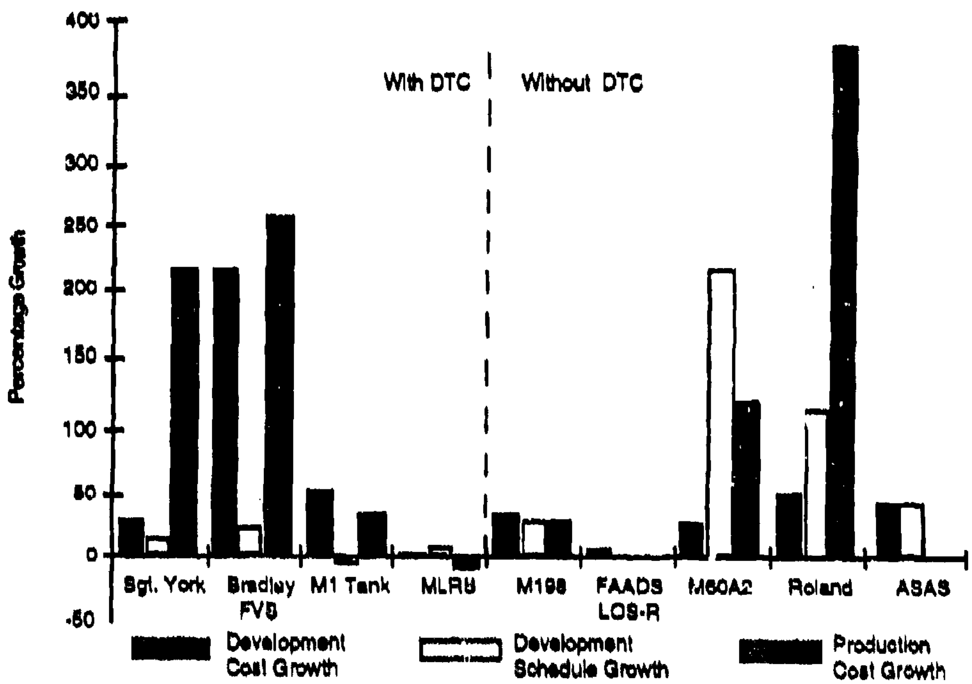


Figure II-4. Outcome Measures for Programs With and Without Design-to-Cost

e. Firm Fixed-Price Development

Only one ground combat program used firm fixed-price development (FPD), the Sgt. York gun system, the only FPD program in our database that was canceled because of performance problems. The weakness of FPD in the Sgt. York program was probably due both to difficulty with the technical performance of the system and to the limited resources available to the contractor. While the development cost outcome for the Sgt. York looks good, the program was highly concurrent, and the production cost growth was very high. Development problems spilled over into production (Figure II-5).

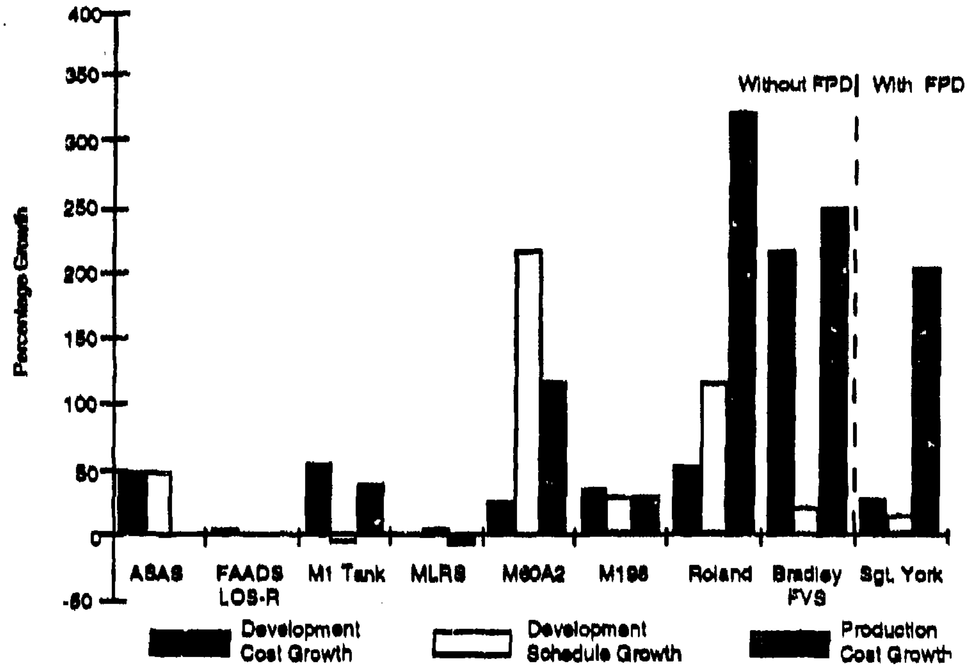


Figure II-5. Outcome Measures for Programs With and Without Fixed-Price Development

f. Contract Incentives

The results on contract incentives (Figure II-6) are skewed by the presence of two failed programs. The technical shortcomings of the Roland and the Sgt. York probably cannot be blamed on incentive contracting. The only other program with incentive contracts in both development and production was the M1 tank, and its results are about in the middle of the other ground combat programs. Bradley and MLRS had incentives in development only—cost growth was high for Bradley and low for MLRS. From this evidence, we can see no consistent pattern of impact of incentive contracting in ground combat programs.

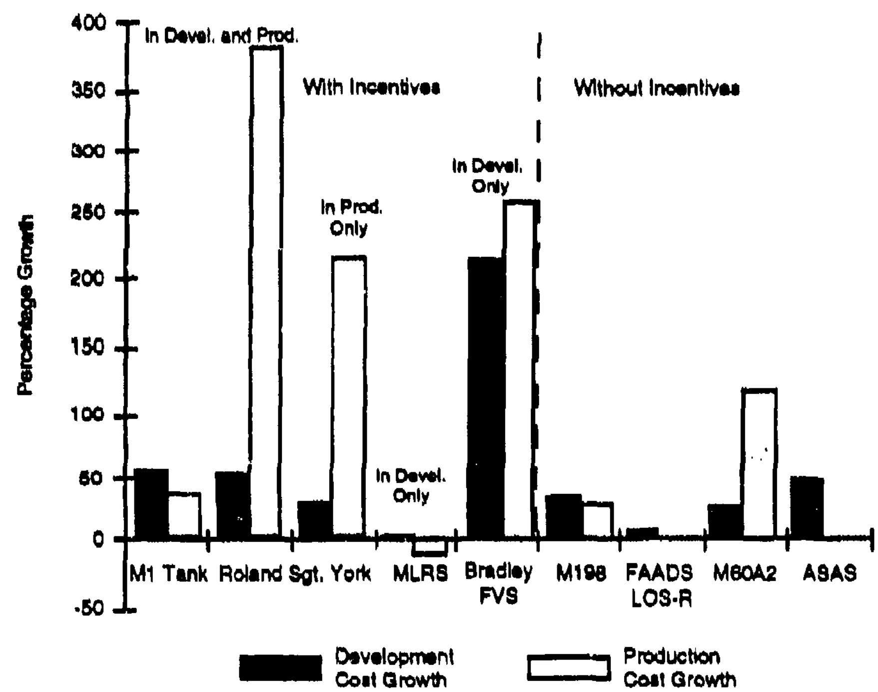


Figure II-6. Development and Production Cost Growth for Programs With and Without Contract Incentives in Development and Production

B. CASE STUDIES

The case studies in this section describe the background, estimate the cost, and identify the acquisition initiatives for each of the programs in our study.

1. FAADS LOS-R (Avenger)

As a result of the cancellation of the DIVAD program (see subsection 2 on the Sgt. York gun), the Army adopted an air defense plan known as the Forward Area Air Defense System (FAADS), which consisted of five elements: (1) a line-of-sight forward (LOS-F) system consisting of an existing mobile air defense missile system supplemented with air defense guns; (2) a line-of-sight rear (LOS-R) system consisting of Stinger missiles to be mounted on an existing Army vehicle; (3) advanced development of an existing, longer range, non-line-of-sight (N-LOS) missile such as the Fiber Optic Guided Missile (FOG-M); (4) improved air defense surveillance and command, control and intelligence systems; (5) upgraded M1 Abrams tank and Bradley M1 Infantry Fighting Vehicle/M3 Cavalry

Fighting Vehicle to provide some air defense capabilities. Avenger was selected as the FAADS LOS-R.

The information in the subsections that follow was derived from Reference [2] and the SARs for the program.

a. System Description

The Avenger system is a lightweight, highly mobile and transportable surface-to-air missile/0.50 caliber machine gun system. It is operated by a two-person crew for defense against helicopters and fixed-wing aircraft at low altitude in day or night operations and in clear or adverse weather. The system is mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV) and incorporates an operator's position with controls and displays, fire control electronics, and a Standard Vehicle Mounted Launcher (SVML) to support and launch multiple Stinger missiles. The SVML provides output signals to display to the gunner exactly where the Stinger missile is pointed. The system interfaces and functions with standard, unmodified Basic Stinger, Stinger-POST, and Stinger-RMP missile rounds. The Avenger incorporates a 0.50 caliber machine gun to provide attrition and suppression of threat aircraft operation, ranging from degradation of ordnance delivery accuracy to total abort of mission.

The LOS-R fire unit provides the man/machine interface to maximize Stinger missile operational effectiveness in the threat environment.

b. Acquisition Background

In January 1986, OSD approved in principle an integrated air defense program to meet the growing air threat to the forward area of the battle field. The components of FAADS are not new to air defense. The military has planned for command, control and intelligence (C^2I) and had a requirement for improved air defense weapons for several years. The FAADS programs, using a systems approach, will integrate these relatively independent systems together to defeat the future enemy threat in the forward area. The acquisition strategy relies heavily on non-developmental items (NDIs) and pre-planned product improvement (P^3I) to rapidly overcome the current air defense deficiencies and keep pace with the advancing threat.

The NDI request for proposals (RFP) was issued in July 1986, and in August 1987 a production contract was awarded to Boeing Company. This contract provided for the production of 20 LOS-R units and for support in areas such as product assurance, configuration management, test and evaluation, and logistics planning. The contract had

five additional options for a total production of 273 units to be delivered through December 1993, and for contractor integration of fielded items. Option II of the contract was awarded in March 1988 for 39 units. The program was re-baselined in 1988 from a planning estimate to a production estimate. On 12 April 1990, the Defense Acquisition Board (DAB) granted the necessary decision for full-scale production of Avenger. System production is scheduled to end in FY 1997.

c. Program Costs

The development estimate was $11.7 million for development and $1,045.9 million for production (FY 1987 dollars). In 1988, the Army used an adjustment factor of 1.0722 (OSD Inflation Indices dated 23 December 1988) to re-baseline program costs (both development cost and production cost) from FY 1987 to FY 1989 to get the current estimate of program costs. For our analysis, we used official OSD deflators dated 7 January 1990. In FY 1989 constant dollars, the Avenger baseline development cost estimate is $12.6 million and the baseline production cost estimate is $1132.6 million. All Avenger research, development, test and evaluation (RDT&E) funds were shared with Stinger, and FY 1987 procurement funds ($41.2 million) were shared with Stinger. Because of the lack of production experience, the production data were not used in the analysis. The schedule and cost data for FAADS LOS-R are summarized in Table II-8.

Table II-8. FAADS LOS-R Program Schedule and Cost Summary

	Development Estimate (12/86)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Nov-86	Nov-86	N/A
End Date (IOC)	Sep-89	Sep-89	N/A
Quantity	0	0	N/A
Cost	$12.7	$13.3	N/A
Production			
Start Date	Aug-87	Aug-87	Aug-87
End Date	Sep-97	Sep-97	Sep-97
Quantity	1,207	1,207	1,207
Cost	$1,132.6	$1,053.6	$1,053.6
Program Status			
Development—Completed			
Production—3 years of data			

Note: Costs are in millions of base-year 1989 dollars. N/A means not applicable.

d. Acquisition Initiatives

Since the FAADS LOS-R acquisition strategy relies heavily on NDIs and P³I, an NDI-candidate evaluation based on current performance and growth capability of contractors was conducted for nine months (November 1986–July 1987) before the FAADS LOS-R production contract was awarded. In our database, we considered this to represent competition in advanced development (AD) and FSD. The Avenger was not subjected to prototyping, design-to-cost, multi-year procurement, total package procurement, on firm fixed-price development.

2. Sgt. York Gun (DIVAD)

Designed in the mid-1970s, the DIVAD was intended to replace the Vulcan 20mm antiaircraft gun, in the Army's inventory since the late 1960s, and to defend the Army's most forward-deployed forces against potential attack by enemy fighter bombers and attack helicopters. However, when finally produced and tested during 1984 and 1985, the DIVAD proved incapable of overcoming the threat postulated for the 1990s. Furthermore, its unit cost—over $6 million—severely limited the potential number of guns that could be purchased and deployed with Army forces. The Sgt. York program was canceled in August 1985 by the Secretary of Defense.

The following subsections contain information from Reference [2] and the SARs for the program.

a. System Description

The Sgt. York gun is a self-propelled medium-caliber (40mm) air defense gun using a modified M48A5 tank chassis. It was designed to be transportable in C-5A aircraft. The system was designed to provide increased kill probability and effective range over existing weapons and improve reliability, maintainability, and mobility over the Vulcan Air Defense System in use in the U.S. Army. The Sgt. York gun was to be employed in the air defense artillery battalions of the armored and mechanized divisions, the corps air defense artillery group, and armored cavalry regiments. The weapon, in addition to its air defense role, was to be used in a ground support role against lightly armored vehicles and personnel carriers.

b. Acquisition Background

Formal development of the Sgt. York gun began in August 1976 with the approval of the required operational capability (ROC) by the Department of the Army. Defense

Systems Acquisition Review Council (DSARC) I was held during February 1977. OSD ordered a revision of the ROC based on its own review of the Cost and Operational Effectiveness Analysis (COEA) as well as other DoD and Army comments. The new ROC was approved on 16 March 1977, and the RFP was issued on 26 April 1977. DSARC II was held during November 1977. After some follow-on analysis, OSD concurred in the COEA results and announced that the Army could proceed with the current program on 6 January 1978. Firm fixed-price, best-effort Engineering Development contracts of $39.6 million and $39.1 million were awarded to two contractors, Ford Aerospace and Communications Corporation (FACC), and General Dynamics Corporation, in January 1978. The contracts called for delivery of two vehicles in 29 months for Army testing and evaluation. Additional requirements included validated computer simulation models and firm cost proposals for the first three production options. While some analysts have referred to this phase as a prototyping program, the contract was awarded after the Milestone II meeting and this does not fit our definition of a prototype. The accelerated acquisition strategy employed was a factor in the program's lack of success (see Reference [3]).

Comprehensive field tests were conducted for five months during which both Ford prototypes were used in stationary and mobile roles. Every full-scale aerial target presented was shot down using either the proximity-fuzed prefragmented ammunition or the point-detonating ammunition as chosen automatically by the fire-control computer. Simultaneously, the Army Material Systems Analysis Agency evaluated the contractors' computer simulation models to obtain estimates of system performance under simulated battlefield conditions that could not be field tested due to cost, time, or safety considerations. Based on the field test results, output from the computer simulations and the contractors' proposals for the production program, the Army awarded FACC a contract to produce DIVAD on 7 May 1981. It was a fixed-price incentive fee (firm targets) contract that included a firm buy for FY 1981 with three optional buys for FYs 1982, 1983, and 1984. The DIVAD gun system was then officially named Sgt. York in honor of the World War I hero Sgt. Alvin C. York.

The FY 1982 buy option for 50 fire units, ammunition and support equipment was awarded in May 1982. First production was delivered in March 1984, six months behind schedule. The Army exercised Option II of its contract with FACC for the production and delivery of 96 fire units in May 1983.

During 1984, the Sgt. York program went through several major developments, including: the Secretary of Defense's direction to conduct Operational Test (Follow-on

Evaluation, FOE) during April-May 1985 before awarding the FY 1984 buy of 117 fire units; congressional action to delete the buy of fire units in FY 1985 but authorize the expenditure of $100 million advanced procurement, subject to a successful FOE; the award to Ford Aerospace of an anticipatory cost contract that allowed the expenditure of up to $200 million (FY 1984 dollars) in anticipation of the Option III award in July-September 1985; and the approval of major Product Improvements to integrate the Stinger missile into the Sgt. York fire control system beginning in FY 1986.

Substantial program cost growth was due to difficulties in transition from full-scale development interface problems, and overtime expended to make up schedule losses.

The Sgt. York program was canceled by DoD on 27 August 1985. Work on Option II of the production contract was terminated at 14 fire units instead of 96 as originally planned.

c. Program Costs

Program costs and schedule data were obtained from the March 1978 through December 1985 SARs and are summarized in Table II-9.

Table II-9. Sgt. York (DIVAD) Program Schedule and Cost Summary

	Development Estimate (3/78)	Current Estimate (9/85)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Feb-77	Nov-77	N/A
End Date (IOC)	Mar-85	Mar-87	N/A
Quantity	4	4	N/A
Cost	$162.9	$211.1	N/A
Production			
Start Date	Oct-80	May-82	May-82
End Date	Aug-87	Sep-85	Sep-85
Quantity	618	64	618
Cost	$2,043.4	$943.8	$6,456.5
Program Status			
Development—Completed			
Production—Completed			

Note: Costs are in millions of base-year 1978 dollars. N/A means not applicable.

d. Acquisition Initiatives

Four acquisition initiatives have been applied to the Sgt. York program:

- Design-to-cost,
- Competition in full scale development,
- Firm fixed-price development, and
- Fixed-price incentive contract in production.

The program was not subjected to prototyping, multi-year procurement, or total package procurement.

3. MLRS

The Multiple-Launch Rocket System (MLRS) is a cooperative program among the United States, France, Germany, the United Kingdom, and Italy. Most of the information that follows is from Reference [2] and the program SARs.

a. System Description

The MLRS is a highly mobile automatic rocket system developed to enable a firing crew with a minimum amount of training to shoot a complete 12-rocket load, reload rapidly and fire again. It is designed to supplement cannon weapons to deliver a large volume of firepower very quickly against critical, time-sensitive targets. This artillery rocket program was initially known as the general support rocket system (GSRS), which designation applied from 1972 to December 1979, when the name was changed in the interests of uniformity and acknowledgment of the system's adoption as the NATO standard rocket. A memorandum of understanding (MOU) covering the intended adoption of MLRS by Britain, France, and Germany was concluded by these states and the United States (Italy joined the group in 1982).

The system consists of a launcher, two disposable pods containing either six rockets or one missile each, a fire control system, and an azimuth/position reference unit. The carrier is a derivative of the Bradley Fighting Vehicle, which used the same engine, transmission, and other mechanical systems. The carrier, when configured for MLRS, is designated M993. The rockets are loaded in the launch pods at the factory, shipped and stored in the pods, and fired from the pods. Fuse settings are accomplished automatically by the fire control system.

b. Acquisition Background

U.S. Army MLRS concept definition study contracts were awarded in March 1976 and completed later that year. In January 1977, the DSARC I approved MLRS to enter validation with two competitive contractors and an option to later enter low-rate production (LRP) with either one or two primes. The validation phase consisted of competitive development contracts signed in September 1977 with Boeing, Seattle and LTV Aerospace and Defense Company (formerly Vought Corporation) for a 29-month competitive development. This phase was extended to 32 months in January 1978 to incorporate design changes to satisfy the German requirement for a scatterable mine warhead. The validation phase of the program was successfully completed on schedule, within cost, and within development test/operational test thresholds.

In April 1980 the Army selected LTV as prime contractor for MLRS. Subsequent funding was awarded under four separate contracts (maturation research and development, initial production facilities, low-rate production, and multi-year procurement). Initial production began in early 1982. Initial operational capability (IOC) was accomplished on schedule in March 1983 with the fielding of the first battery at Ft. Riley. The first European battery was deployed in September 1983 at Baumholder, Germany. As of December 1989, three firm fixed-price procurement contracts had been signed. The first multi-year contract was awarded in September 1983 following an extensive "should cost" analysis to cover a five-year firm fixed-price contract (with economic price adjustment clause) for production of 149 launchers, 55,726 tactical rounds, and 4,060 practice rounds for a price target of $1,582.7 million then-year dollars with a negotiated two-year option (FY 1988-FY 1989). The two-year option procurement contract was awarded 1 June 1987. It was for production of 70 MLRS launchers for a target price of $79.8 million then-year dollars. The second multi-year procurement contract was awarded 30 June 1989 for a five-year period (FY 1989–FY 1993). It was for production of 262 launchers, 106,278 tactical rockets, and 17,508 practice rockets for a target price of $1,079.1 million then-year dollars. MLRS procurement is scheduled to end in 1994.

c. Program Costs

The program has an RDT&E cost of $267.7 million for a development quantity of 10 launchers and 504 rockets. This cost does not include $37.6 (escalated) funding by MOU participants. The current estimate of the production cost is $2,703.0 million for a production quantity of 840 launchers and 567,528 rockets. In the SAR, program acquisition costs are not broken down by launcher and rockets, they include both the

launchers and rockets. To more accurately measure production cost, the Army Cost and Economic Analysis Center (CEAC) provided us with production costs separated by launchers, rockets, and practice rounds. We developed price improvement curves to calculate current estimates of production cost by component. We then added those together to get current estimates of total production cost. The schedule and cost data for MLRS are summarized in Table II-10.

Table II-10. MLRS Program Schedule and Cost Summary

	Development Estimate (12/79)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Jan-77	Jan-77	N/A
End Date (IOC)	Nov-82	Mar-83	N/A
Quantity	654	504	N/A
Cost	$261.3	$267.7	N/A
Production			
Start Date	May-80	May-80	May-80
End Date	Sep-88	Sep-94	Sep-94
Quantity	2,906	4813	2,906
Cost	$1,971.3	$2,703	$1,736.9
Program Status			
Development—Completed			
Production—11 years of data			

Note: Costs are in millions of base-year 1978 dollars. N/A means not applicable.

d. Acquisition Initiatives

Five acquisition initiatives have been applied to MLRS procurement:

- Prototyping in development,
- Advanced development and full-scale development competition,
- Design-to-cost,
- Multi-year procurement, and
- Incentive contracts in advanced development and FSD.

Apparently, the MLRS was not subjected to firm fixed-price development or total package procurement.

4. Roland

Roland is a compact, mobile, all-weather system. Originally designed for the French and German armies, it is a superior weapon for the close support of fixed installations and troops against low-level, high-speed air offensive action. The major variants of Roland include the following:

- Roland I—a clear-weather version equipped with only a search radar,
- Roland II—an all-weather system that utilized both a search and a fire control radar,
- MIM-115—a U.S.-licensed and -produced version of the Roland II,
- Roland III—latest variant of the missile upgraded to increase speed and range, and
- RM-5—a hypervelocity missile planned to meet the next generation of air threats.

Roland was selected by the U.S. Army in late 1974 to meet its Short-Range Air Defense System (SHORADS) requirement, but engineering changes and continuous funding problems delayed procurement until June 1979.

Much of the information that follows is from Reference [2] and the program SARs.

a. System Description

The Roland missile system is a mobile, air transportable, short-range, air defense system. It consists of a fire unit, a missile, a carrier vehicle, a trainer and maintenance test sets. The fire unit is fully self-contained in a module that can be in a fixed position or mounted on a variety of vehicles and requires no inter-unit cabling. The fire unit consists of a search radar, a tracking radar, a computer, an identification, friend or foe (IFF) unit, an optical sight, two automatic reload launchers and two storage magazines. Ten missiles are carried on the fire unit; two are on the trainable launchers immediately ready for firing, and eight are carried on the magazines. The Roland was to replace the Chaparral in the corps area. In the field army, Roland was to provide an all-weather, day or night defense of high-value targets against high-performance, low-flying aircraft.

b. Acquisition Background

In 1973, the U.S. Army required an all-weather, low-altitude air defense missile system. The Army initiated a program to evaluate three foreign systems that were under development: the French Crotale, the British Rapier/Blindfire, and the German and French Roland. All three systems could, with minimal changes, meet the U.S. requirements. The

Army chose the Roland. The U.S. Roland Development Concept Paper was approved in April 1974. A contract for the Technology Transfer, Fabrication and Test (TTF&T) of the German and French Roland system was awarded to Hughes Aircraft Company on 9 January 1975.

Because of the potential cost growth associated with the TTF&T contract identified by the contractor, the program was restructured on 24 September 1976. The restructured program made maximum use of joint U.S. and European testing to assure missile-level international interchangeability. The program planned to condense U.S. system testing by integrating the normal proving qualification test–contractor, proving qualification test–government, and operational test II programs. In October 1976, the Hughes contract was modified to finalize the remaining TTF&T effort [4].

A DSARC III was held on 31 May 1979 to authorize production of the U.S. Roland. In June 1979, initial low-rate production contracts (FYs 1979, 1980, and 1981) were awarded to associated contractors—Hughes Aircraft Company and Boeing Aerospace Company. Congress terminated the program in 1982.

The Roland program never fulfilled its promise. The biggest reason for the cost growth in the Roland program was technical overreaching. The European system worked, but the U.S. demanded additional capabilities for the system, including electronic countermeasures, a more powerful radar, and hardening to withstand nuclear, biological, and chemical attack. In addition, several devices had to be included to meet higher U.S. safety standards.

A secondary reason was the decision to require U.S. production of the missile, thus avoiding dependency on foreign suppliers, but adding greatly to costs. The U.S. government required that qualified U.S. sources for parts be obtained, even though the parts would be manufactured in Europe. Military specifications had to be met, even though missiles manufactured without these standards were protecting U.S. bases in Europe.

By the time that the Roland was ready to be produced, the Chaparral system was found to provide sufficient defense except during heavy weather (about 15 percent of the time). The Roland program was then canceled, but it was a "soft termination" that allowed the contractors to fulfill an existing contract for 27 vehicles and 595 missiles [5]. The existing systems were retained for operations by units of the Rapid Deployment Force, but in June 1984, the Army announced it would sell all Roland equipment in U.S. inventories. After unsuccessfully trying to negotiate a sales agreement with Turkey, the missiles were

handed over to a unit of the New Mexico National Guard. The unit was later deactivated to save the $50 million annual cost of maintaining the missiles.

c. Program Costs

The schedule and cost data for Roland are summarized in Table II-11.

Table II-11. Roland Program Schedule and Cost Summary

	Development Estimate (12/75)	Current Estimate (3/82)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Jan-75	Jan-75	N/A
End Date (IOC)	Jun-79	Jul-84	N/A
Quantity	4	4	N/A
Cost	$160.2	$244.2	N/A
Production			
Start Date	Apr-78	May-79	May-79
End Date	Sep-83	Sep-81	Sep-81
Quantity	180	27	180
Cost	$677.8	$654.6	$3,270.8
Program Status			
Development--Completed			
Production—Completed			

Note: Costs are in millions of base-year 1975 dollars. N/A means not applicable.

d. Acquisition Initiatives

Contract incentives were used in both FSD and production phases of the program. Since the program development consisted of the transfer to the United States of an existing European design, other acquisition initiatives were not applied to this program.

5. M1 Abrams Tank

The M1 main battle tank (MBT) program began after the cancellation of the joint United States/German MBT 70 and XM803 projects of 1970 and 1971, which were terminated by Congress due to excessive costs. The information in the following subsections is from Reference [2] and the program SARs.

a. System Description

The Abrams tank provides a significant improvement to the Army offensive and defensive vehicle power. It mounts a large-caliber main gun and three complementary

armament systems with improved day and night fire control and shoot-on-the-move capabilities. Its high cross-country speeds and fast acceleration make the Abrams tank a more difficult target for opposing ground and air forces. Major improvements of the M1 over the previous M60 series can be summarized as improved protection, mobility, firepower, and reliability, availability, maintainability and durability (RAM-D).

b. Acquisition Background

The M1 Abrams Tank program was formally approved in January 1973. On 28 June 1973, competitive contracts for the prototype development validation phase of the XM1 were awarded to two contractors: Detroit Diesel Division of General Motors and the Defense Division of Chrysler Corporation. Each contractor was required to develop a tank that met the material need requirements while remaining within an average design-to-unit hardware cost of $507,790 in 1972 dollars for production tanks. Thirty-six months of engineering development resulted in the competitive selection of Chrysler Corporation as the prime contractor in November 1976.

A Full Scale Engineering Development (FSED)/Producibility Engineering and Planning (PEP) contract for the first-generation tank was awarded on 12 November 1976. It was a three-year contract worth $196.2 million for the FSED phase, during which 11 XM1 pilot vehicles with their associated spares were produced [6]. In February 1978 the first pilot vehicle was delivered to the Army. After a five-month (March 1978–July 1978) operational and development test, numerous technical shortfalls had been identified. These included the air induction system, hydraulic and fuel management systems, engine, and the track and suspension system. Basically, these deficiencies resulted in an unsatisfactory rating for mission and power train durability. These defects extended testing through September 1979, a total of 18 months of testing. Nevertheless, during April 1979, the U.S. Army's review council authorized the first production year buy of 110 M1 tanks with FY 1980 funding. This buy of the M1 was primarily for extensive Phase III operational testing. Testing continued on a number of pre-production as well as production tanks under the U.S. Army's long-range improvement program

In August 1984, the Army Systems Acquisition Review Council (ASARC) approved production of the improved M1A1 tank. Total production of the 105mm M1 Abrams amounted to 3,268 tanks and was finished in February 1985 when production switched solely to the Improved M1 with improved armor protection.

On 2 December 1988, the Defense Acquisition Board (DAB) gave its conditional approval for the Block II improvement program. The M1A2 Full Scale Development (FSD) contract was awarded on 14 December 1988.

On 25 January 1989, an Acquisition Decision Memorandum was issued to allow the Army to proceed with M1A2 modernization program pending the publication of a complete Cost and Operational Effectiveness Analysis (COEA). On 18 October 1989 the memorandum was signed that established a FY 1991–1997 procurement objective of 2,926 third-generation Abrams Tanks (M1A2). However, later budget decisions eliminated all Abrams tank procurement funding after FY 1991 and established a FY 1991 procurement objective of 62 M1A2s to demonstrate readiness for continued production at level rates.

The procurement contracts (from year 1 to 2) awarded to Chrysler Corporation that were transferred to General Dynamics Land Systems (GDLS) in March 1982 because Chrysler's Tank Building Subsidiary was sold to GDLS. From year 3 to year 7 of production the contracts were awarded yearly. From year 8 to 12 the contract was awarded as a multi-year procurement.

The debate over whether to equip the M1 with an AGT 1500 gas turbine engine or a conventional diesel-powered engine led Congress to mandate additional testing of a diesel engine in the M1 in 1986. In the early 1980s, the Army had run a parallel but low-profile validation of an advanced diesel engine, initially called the AVCR-1360. An $11.6-million contract was signed with Teledyne Continental Motors in May 1980 to build two AVCR-1360 engines and to modify two XM1 prototype tanks for extensive governmental testing. A subcontract was awarded to General Motors in August 1980 for design and fabrication of the gear box modifications that were completed during mid-1982. The program was to identify the engine and vehicle changes that would be required if a decision would be made to switch to a diesel power plant. The total cost of the AVCG-1360 diesel engine program is said to be approximately $400 million. With this program, the Army was complying with congressional mandates while proceeding with complete integration of the AGT 1500 into the M1 production facilities. Because of this mature status of the program and the fact that the AVCG-1360 experienced troubles in testing, it is almost certain that this power plant will never be incorporated into production M1 tanks. The AVCG-1360 program has been terminated.

The ongoing enhancements have resulted in a number of M1 models:

- Basic M1—the basic tank with the M68 cannon. In addition to 12 prototypes, serial production funding ran from 1979 to 1983.

- Improved M1—the basic tank with a number of interior survivability enhancements as well as an upgraded suspension. Production of this version was concurrent with the basic M1 and was funded in 1983 and 1984.
- M1A1 (also called M1 Block I)—following production of 14 prototype XM1E1 vehicles. This model incorporates the M256 120mm cannon, ordnance shield, integrated nuclear, biological and chemical system, including environmental control system, upgraded final drive and suspension, a wrap-around storage rack on the extended turret, new ammunition storage and improved blow-off panels.
- M1A2 (M1 Block II)—intended to have the improved commander's station, an independent panoramic thermal sight for the commander, an eye-safe carbon dioxide laser rangefinder, a thermal viewer for the driver, IFF system, an integrated command and control system, a land navigation system and other component improvements for enhanced survivability. Due to funding and other problems, as of early 1991, some of these enhancements have yet to be funded for the production tanks. The fiscal 1991 budget funded only 62 units of this model.

Production funding schedule and quantity by model are summarized in Table II-12 and Table II-13.

Table II-12. M1 Abrams Tank Production Quantity Funding Segregated by Version

Buy	Fiscal Year	Basic M1	Imp. M1	M1A1	Total
1	79	90	—	—	90
2	80	309	—	—	309
3	81	569	—	—	569
4	82	665	—	—	665
5	83	741	114	—	855
6	84	—	780	60	840
7	85	—	—	854	854
8	86	—	—	811	811
9	87	—	—	810	810
10	88	—	—	725	725
11	89	—	—	555	555
12	90	—	—	481	481
13	91	—	—	225	225
	Totals	2,374	894	4,521	7,789

Sources: Total production quantity based on the 31 December 1990 SAR. Production quantity breakout by version provided by the Army CEAC, J. W. Gamble.

Table II-13. M1 Abrams Series Tank Production

Series	Total Year Buy	Fiscal Year	Quantity
Basic M1	5	79-83	2,374
Imp. M1	2	83-84	894
M1A1	6	84-91	4,521
Total	13	79-91	7,789

Sources: 31 December 1990 SAR; Army CEAC, J. W. Gamble.

c. Program Costs

The program cost was re-baselined in 1989 from FY 1972 base-year dollars to FY 1989 base-year dollars. The SAR does not report cost by tank series as for the milestones, instead it reports total program cost as a whole. For an accurate cost growth measure, our analysis will focus on the M1 MBT (original version). Production quantity breakdowns by version were obtained from the Army CEAC. Cost and schedule data for the M1 Abrams tank are from the December 1983 SAR (when the original version funding ended) for development, and the 31 December 1989 SAR for production. These cost and schedule measures are summarized in Table II-14.

Table II-14. M1 Abrams Tank (Original Version) Program Schedule and Cost Summary

	Development Estimate (12/77)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Jul-76	Nov-76	N/A
End Date (IOC)	Dec-80	Jan-81	N/A
Quantity	13	13	N/A
Cost	$422.6	$648.8	N/A
Production			
Start Date	Feb-79	Apr-79	Apr-79
End Date	Sep-88	Sep-83	Sep-83
Quantity	3,312	2,374[a]	3,312
Cost	$1,970.2	$2,024	$2,685.3
Program Status			
Development—Completed			
Production—Completed			

Note: Costs are in millions of base-year 1972 dollars. N/A means not applicable.
[a] M1 quantity only; later variants not included.

The M1 Abrams tank is considered to represent mature technology, but it is the first tank with a gas turbine engine as its main propulsion.

d. Acquisition Initiatives

Six acquisition initiatives have been applied to the M1 Abrams tank:

- Dual-sourcing in FSD,
- Prototyping,
- Design-to-cost,
- Contract incentives in FSD, and
- Contract incentives in produc ion.

6. Bradley FVS

The Bradley FVS is an outgrowth of the plan to develop and test the predecessor Mechanized Infantry Combat Vehicle (MICV). Entering engineering development in November 1972 as MICV, the Bradley FVS has been modified three times.

Most of the information that follows is from Reference [2] and the program SARs.

a. System Description

The Bradley Infantry Fighting Vehicle (IFV) and Cavalry Fighting Vehicle (CFV) are fully tracked, lightly armored vehicles that provide protected cross-country mobility and vehicle-mounted firepower to infantry/cavalry units. The IFV/CFV have swimming capability and are air transportable. Vehicle armament consists of a fully stabilized, dual-feed, externally powered M242 25mm automatic gun as its primary weapon, a tube-launched, optically tracked, wire-guided (TOW) missile system, and a M240C 7.62mm coaxially-mounted machine gun. Supplementary armament for the IFV is the M231 firing port weapon.

The product-improved IFV/CFV versions incorporate improvements in missile performance, operations in a nuclear, biological, and chemical (NBC) environment, fightability, survivability, and other functions. The M2A2/M3A2 incorporate improved armor protection, spall protection liners, and minor modifications such as restowages. The IFV/CFV introduces a formidable fighting vehicle into the Army forces.

b. Acquisition Background

The first U.S. MICV was the XM701(also known as MICV-65), five prototypes of which were completed by Pacific Car and Foundry in 1965. The XM701 was not developed past the prototype stage because tests of military potential were not successful and it was not airportable in a Lockheed C-141 transport aircraft.

In 1967, the FMC Corporation was awarded a contract with the Army to build two candidate infantry fighting vehicles. These models were not adopted by the Army, but further development by FMC, as a private venture several years later, resulted in the Armored Infantry Fighting Vehicle (AIFV) later designated XM765 (currently in service with the Netherlands, the Philippines, Belgium, and Turkey), and the XM723.

In April 1972, the Army issued an RFP for a new MICV. Six companies responded, and three were selected (Chrysler Corporation, FMC Corporation, and Pacific Car and Foundry) to develop cost estimates and design prototypes. In November 1972, FMC was awarded a $29.3 million cost plus incentive fee (CPIF) contract for Engineering Development and Advanced Production Engineering. This contract covered the cost of the design, development and fabrication of three prototype vehicles, a ballistic vehicle, 12 pilot vehicles, and associated systems engineering, product assurance, and test support. The prototypes, called XM 723, were completed by the summer 1975.

The MICV could not be built to meet the required the 35,000-pound to 38,000-pound weight band, resulting in the weight specification being changed to 43,000 pounds. The actual weight of the first ED vehicle was 43,700 pounds. These increases are attributed to cost tradeoffs (substitution of steel for titanium bars) and design changes required primarily to meet reliability and durability requirements in the mobility area. In 1975 the Army had rejected two prototype designs for its Armored Reconnaissance Scout Vehicle and directed the project's staff to work with the prototype XM723 as the baseline cavalry vehicle. To consolidate the task forces, the Army combined both cavalry and infantry fighting vehicle requirements under the Mechanized Infantry Combat Vehicle program in August 1976. At the same time, under request by Congress, a task force was formed by the Army to evaluate the whole XM723 program to determine whether the vehicle would meet the future requirement of the Army. The Task Force recommended a new program called the Fighting Vehicle System consisting of two vehicles: the XM2 Infantry Fighting Vehicle and the XM3 Cavalry Fighting Vehicle. Recommendations for the new vehicle system included:

- A common vehicle would be developed for both the infantry and scout roles as the armored reconnaissance scout vehicle.

- The vehicle would be fitted with the TOW ATGW launcher system and 25mm cannon in a two-man TOW/Bushmaster Armored Turret (TBAT-II). A two-tube TOW ATGW launcher would be mounted on the left side of the turret to give the vehicle an antitank capability.
- The firing ports would be retained.
- The vehicle would be amphibious.
- The vehicle would have the same level of armored protection as the XM723.
- The vehicle would be issued on the scale of four per platoon, 13 per company, and 41 per battalion.

In November 1976, the Secretary of the Army approved development of the IFV/CFV 25mm/TOW. In April 1977, after five years in development, the MICV 20mm program, which was continuing concurrently, was terminated and the program assets and funding were transferred to the new program.

In 1979 the program was re-baselined. The M2/M3 production contract was awarded to FMC Corporation in February 1980, for 100 vehicles with FY 1980 funding, 400 with FY 1981, 600 with FY 1982, 600 with FY 1983, and another 600 with FY 1984. The first production contract deliveries of 100 vehicles were completed on schedule in July 1982. The program reached IOC in December 1983.

In October 1980, OSD approved the start of the TOW 2 development program.

On 20 October 1981, the M2 IFV/M3 CFV was dedicated the Bradley Fighting Vehicle. A comprehensive Block 1 modification program (A1) was initiated in July 1983. The M2A1/M3A1 entered production in July 1985, and reached IOC in November 1988. The M2A1/M3A1 can fire all versions of the Hughes TOW ATGW, including the full diameter TOW 2.

A Block 2 development program (A2) was initiated in October 1985 to provide increased survivability changes and improvements into production vehicles. On 10 September 1987, incorporation of survivability improvements (addition of 30mm high-survivability protection) into the FVS acquisition program was approved. The M2A2/M3A2 entered production in October 1987, and reached IOC in August 1989.

In early 1990, the Army cut its planned procurement of the M2/M3 Bradley from 8,811 to 6,725, and in a move designed to ease the cut's impact on the manufacturer, stretched the production run of the remaining units. A major reason for the reduction in the procurement of the Bradley is the Army's decision to replace the Bradley in its scouting role with the M998 High Mobility Multipurpose Wheeled Vehicle. According to industry

and military officials, the primary reason for cutting Bradley production is not to save money but to allow for a massive restructuring of the reconnaissance mission of armored cavalry units.

The differences among the models and variants of the Bradley FVS are summarized below:

- M2/M3: The M2 and M3 are almost identical; the only differences are that the M3 has a five-man crew, no firing ports, and a greater ammunition capacity.
- M2A1/M3A1: The improved A1 models of the M2 and M3 entered production in mid-1985 and were first delivered in mid-1986. The differences in these models are:
  - ability to fire the newer TOW 2 missile;
  - improvements to the NBC defense system (individual protection is now provided for the infantrymen);
  - the AN/TAS-5 night sight (for the M2A1) provided by Kollsman allows use of the PGM-77 Dragon antitank missile;
  - firing ports have been replaced by armor (M3A1);
  - the seats (M3A1) can be raised or lowered as needed;
  - increased mine and reduced flare storage (M2A1);
  - four periscopes and an engine smoke generator in the missile-loading hatch (M3A1);
  - modified fire detection/suppression equipment; and
  - modified fuel system.
- M2A2/M3A2: The Bradley FVS began a two-phase block modification program in fiscal year 1985 to incorporate preplanned product improvements:
  - Block I modifications were introduced to the production line in May 1986, resulting in two new versions of the Bradley FVS: the M2A1 Infantry Fighting Vehicle (IFV) and the M3A1 Cavalry Fighting Vehicle (CFV). These modifications consist of improvements to both vehicles' NBC system, weapon system interlock, stowage, integration of the TOW 2 missile, and a new rear-vision hatch for the M3A1.
  - The Block II effort consists of upgrades of the 25mm ammunition, armor protection, and overall vehicle survivability. The M2A2 and M3A2, the latest production standard, integrate additional survivability and other features; most of these features are expected to be incorporated as retrofits to older vehicles.

Production quantities and funding for each model are shown in Table II-15 and Table II-16.

Table II-15. Bradley FVS Production Quantity Funding Segregated By Model

Buy	Fiscal Year	M2	M3	M2A1/ TOW	M3A1/ TOW	M2A1/ TOW 2	M3A1/ TOW 2	M2A2	M3A2	Total Qty.
1	80	75	25	—	—	—	—	—	—	100
2	81	230	170	—	—	—	—	—	—	400
3	82	328	272	—	—	—	—	—	—	600
4	83	345	255	—	—	—	—	—	—	600
5	84	406	194	—	—	—	—	—	—	600
6	85	—	—	129	226	178	122	—	—	655
7	86	—	—	—	—	389	327	—	—	716
8	87	—	—	—	—	—	—	437	225	662
9	88	—	—	—	—	—	—	334	216	550
10	89	—	—	—	—	—	—	591	51	642
11	90	—	—	—	—	—	—	600	—	600
12	91	—	—	—	—	—	—	600	—	600
	Totals	1,384	916	129	226	567	449	2,562	492	6,725

Sources: Total production quantity based on 31 December 1990 SAR. Quantity breakout by version provided by the Army CEAC, J. W. Gamble.

Table II-16. Summary of the Bradley FVS Production Quantity by Model

Series	Fiscal Year	Quantity
M2/M3	80-84	2,300
M2A1/M3A1 (TOW)	85	355
M2A1/M3A1 (TOW 2)	85-86	1,016
M2A2/M3A2	87-91	3,054
Total		6,725

Sources: 31 December 1990 SAR; Army CEAC, J. W. Gamble.

Despite the fact that the Bradley vehicles are still relatively new in the U.S. arsenal, they have come under a great deal of criticism. The Army has done a number of retrofit programs mainly concerned with the vehicles' survivability and vulnerability, the aspects that have received the greatest criticism.

During the Persian Gulf War, both the Bradley Fighting Vehicle and the Abrams main battle tank were praised for their overall good performance but proved to have some deficiencies. The Bradley exhibited good reliability, lethality, mobility, and range; the A2 model in particular was perceived to have good survivability by the crews. According to the

Army the readiness rates for the Bradley, generally 90 percent or higher during the ground war, indicated its high availability to move, shoot, and communicate during combat. Although the Bradley's performance was very satisfactory, various hardware deficiencies were identified, including leaking radiators, unreliable heaters, and misdirected exhaust. The Abrams tank also received high marks for reliability, lethality, survivability, and mobility; however, some system deficiencies were identified that limited the range of the tank. With a readiness rate of 90 percent or higher, the Abrams proved to be fast and powerful, and it maneuvered well in the sand, but it had high fuel consumption, unreliable fuel pumps, and sand ingestion. High fuel consumption limited the tank's range, and refueling the tank was a constant operational concern in the Persian Gulf area, according to the Army [7].

c. Program Costs

The program cost was re-baselined in 1979. The SAR does not report vehicle cost by series, instead it reports total program cost of different vehicle improvements as a whole. For an accurate cost growth measure, our analysis focused on the M2/M3 (original version). We asked the Army CEAC to provide us with the breakdown of production quantity by vehicle improvement series. The original Bradley FVS cost and schedule are summarized in Table II-17.

Table II-17. Bradley FVS (Original Version) Program Schedule and Cost Summary

	Development Estimate (12/77)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Nov-72	Nov-76	N/A
End Date (IOC)	Aug-78	Dec-83	N/A
Quantity	15	21	N/A
Cost	$98.3	$310.5	N/A
Production			
Start Date	Jan-80	Jan-80	Jan-80
End Date	Sep-84	Sep-84	Sep-84
Quantity	1,190	2,300[a]	1,190
Cost	$227.3	$1,304.4	$815.1
Program Status			
Development—Completed			
Production—Completed			

Note: Costs are in millions of base-year 1972 dollars. N/A means not applicable.

[a] M2/M3 production quantity only.

d. Acquisition Initiatives

Three acquisition initiatives have been applied to Bradley FVS:

- Competition in advanced development,
- Prototyping in advanced development, and
- Design-to-cost.

7. M60A2

Development of the M60A2 began in 1964. It consists of an M60 tank chassis fitted with a new turret armed with the Shillelagh weapon system.

The M60A2 model has now been phased out of service with the U.S. Army. A total of 526 M60A2s were built, and most have been sent back to the Anniston Army Depot where they were converted to other uses such as M728 Combat Engineer Vehicles or Counter Obstacle Vehicles.

The information in the following subsections is from Reference [2] and the program SARs.

a. System Description

The M60A2 tank combines the automotive performance of the earlier M60A1 chassis with a new compact turret. Primary armament is the 152mm gun/launcher firing either the Shillelagh missile or the 152mm HEAT-MP-T and Canister rounds. Secondary armament consists of a 7.62mm machine gun (M129) mounted coaxially with the main weapon, a 0.50 caliber machine gun (M85) mounted in the commander's cupola, and two banks of four M226 grenade launchers. The laser rangefinder and ballistic computer combine to upgrade the fire control for the conventional round.

b. Acquisition Background

Development of the M60A2 was approved in December 1964, and in March 1965 the Engineering Development Project was approved. A test system was completed in late 1965 with production beginning late in 1966, before Engineering Test/Service Test (ET/ST) had even been completed. Components for 243 turrets were procured under the FY 1966 program and 300 complete tanks were procured under the FY 1967 program. Failure of the test tanks to complete required tests during ET/ST (due to low reliability and unsatisfactory maintainability of the turret and gun control system), resulted in suspension of ET/ST and cancellation of the planned FY 1969 program to retrofit the new production

M60A1E2 chassis with the previously-procured turrets; 287 chassis from the 300 tanks (FY 1967) were transferred to the M60A2 tank program. A total of 526 M60A2s were built, most of which went straight into storage until problems were solved. Engineering and Service Tests of tanks with improved components were successfully completed in September 1971 following extensive contractor tests. In November 1971, the program was approved to continue through completion of production/retrofit of 540 tanks. Because of the unknowns associated with the long period of storage of M60A2 components, the contract with Chrysler for the retrofit was awarded as a firm fixed-price (FFP) for knowns and cost plus fixed fee (CPFF) for unknowns. The cost to complete the fix of the 540 tanks was estimated to be more than $139 million. The M60A1E2 was redesignated M60A2. A contract was signed 29 November 1971 with Chrysler Corporation for the first year retrofit quantity of 210 tanks. The M60A2 program was initiated prior to the development concept paper, but three thresholds were established: Reliability of production retrofitted M60A2 tanks had to have been demonstrated at not less than 11 mean miles between failure; total remaining retrofit program costs were not to exceed $152.2 million; and the production program would deliver 540 tanks and 32 trainers to service inventory. Retrofit production of the M60A2 began in 1972 and was completed by 1975.

c. **Program Costs**

The RDT&E cost was $17.6 million for a development quantity of three. The procurement cost of 543 tanks was $389.2. This cost did not include the cost for machine guns, radios and intercoms, xenon searchlights and DBR kits estimated at approximately $15,000 per tank. These items were programmed under separate budget lines. Of the production quantity of 543 tanks, 3 were used in all-electric turret backup program; the retrofit program applies to only 526 tanks. Fourteen additional tanks were retrofitted earlier for use in contractor test and ET/ST.

The program procurement cost covered new production of 543 tanks and a retrofit production of 540 tanks. Three production tanks were used to assess the effectiveness of corrective actions taken after the operational durability, reliability, and maintainability tests of the three development test tanks showed lower than expected performance results. There are no funding data reported in this program's SARs (last available SAR, December 1973). The program funding ended in 1973. Since there are no base-year dollars indicated in the SAR, we assumed that program cost was expressed in constant FY 1965 dollars, the year in which full-scale development started. The M60A2 program schedule and cost summary are shown in Table II-18.

Table II-18. M60A2 Program Schedule and Cost Summary

	Development Estimate (12/69)	Current Estimate (12/72)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Mar-65	Mar-65	N/A
End Date (IOC)	Mar-68	Sep-74	N/A
Quantity	3	3	N/A
Cost	$13.7	$17.6	N/A
Production			
Start Date	Aug-67	Mar-68	Mar-68
End Date	Sep-73	Sep-73	Sep-73
Quantity	600	543	600
Cost	$191.9	$389.2	$423.6
Program Status			
Development—Completed			
Production—Completed			

Note: Costs are in millions of base-year 1965 dollars. Base year was not available in the SAR; we assumed FSD start year was the base year. N/A means not applicable.

d. Acquisition Initiatives

No acquisition initiatives were applied to the M60A2 program.

8. ASAS/ENSCE

The Army's All Source Analysis System (ASAS) and the Air Force's Enemy Situation Correlation Element (ENSCE) are the newest versions of their automated tactical intelligence processing systems. ASAS and ENSCE were funded under the former Joint Tactical Fusion Program Office (JTFPO). Both of these efforts involve the use of commercial equipment, NDIs, to automate the collection, evaluation, correlation, and dissemination of intelligence in near real-time. The equipment used to achieve this objective would include a mix of computers, video displays, and secure communications.

Much of the information that follows is from the program SARs.

a. System Description

The ASAS/ENSCE program employed a modular approach to development. This evolutionary development system consists of four modules:

1. ASAS/ENSCE Interface Module (AIM) or Dual AIM (DAIM)—Data Processor Set AN/TYQ-36. It will process intelligence data and provide remote workstation access to the ASAS systems. The AIM can be configured to

operate either within an enclave, communicating on the local area network, or outside of an enclave, communicating via service area communications.

2. The Forward Sensor Interface and Control (FSIC) Module—Communications Control Set AN/TQY-40. This ASAS-only module is a data concentrator that receives and transmits information from multiple sensor systems. Additional functions include voice radio and sensor/electronic warfare management support.

3. Intelligence Data Processing (IDP) Module. This module contains software and analyst workstations. The IDP receives, processes, stores, and transmits information to support analysis, production, and dissemination of military intelligence.

4. Communications Processor and Interface (CPI) Module. This module provides the interface for all voice and data communications for ASAS/ENSCE enclaves. It will accept input from the FSIC (Division only), IDP, and AIM Modules, perform security release and message distribution functions, interface with Service Area Communications and perform internal communications functions.

5. The Portable ASAS/ENSCE Workstations (PAWS). This Work Station Computer Graphics AN/TYQ-37 is one of the major modules of ASAS/ENSCE and the primary user interface to the system. The PAWS consists of a 32-bit computer system with dual high-resolution color graphic displays, local area network access units, and an array of high-capacity computer peripherals. It also incorporates advanced video disk technology for map background display.

b. Acquisition Background

ASAS/ENSCE was developed at congressional request to acquire an Army/Air Force fusion system to meet the critical requirements for an automated intelligence command and control system. Joint Tactical Fusion (JTF) evolved from the signal intelligence/electronic warfare (SIGINT/EW) initiative, an umbrella-type designation covering a variety of electronic programs. In March 1979, RCA's Automated System Division won a $13 million contract for an advanced development model of the SIGINT/EW subsystem of ASAS and for related software. RCA, teamed with HRB Singer to win the award over GTE Sylvania and TRW. During FY 1982, costing of the ASAS required operational capability (ROC) revealed that the system would cost considerably more than originally estimated. An extensive review of the ROC was conducted with the objective of reducing cost by phasing capabilities into ASAS over a period of several years through application of preplanned product improvements into a modest baseline system.

The Jet Propulsion Lab (JPL) was selected as prime contractor for ASAS/ENSCE in March 1983. Full-scale engineering development of the overall program was initiated the same month. A new ASAS acquisition strategy was then initiated. This included revising the program management structure, selecting a system integration contractor, refining system requirements, initiating the software development effort, and completing the preliminary design review. The Army-owned test bed was reconfigured to provide limited fusion capability in Korea.

Martin Marietta was selected in November 1984 to integrate an automated battlefield intelligence data network under the JTFP. Martin Marietta defeated McDonnell Douglas, RCA Government Systems, and GTE Government Systems for this contract. The program started baseline system contract (development) in December 1984, and two major hardware subcontracts were awarded. Martin Marietta became the developer of the AIM, the IDP module, and the workstation and assumed responsibility for overall development coordination of all system modules. Ford Aerospace became the developer for the FSIC and CPI modules. In addition, an ASAS/ENSCE Interface Module Brassboard was built by the JPL. Major subcontractor involvement in software development also began in 1984.

During FY 1985 AIM and FSIC modules were developed to provide a near-real-time processing capability. The System Readiness and Verification Test for these two modules was successfully completed in October 1986. After the test, the equipment was delivered to the field, and field trials were conducted during November and December 1986.

In September 1986 the Assistant Secretary of the Army (Research, Development and Acquisition) approved a limited production (urgent procurement) for the Limited Capability Configurations (LCCs) on behalf of the Army.

In March 1987, a competitive procurement contract was let for production of LCCs. Three LCC systems composed of AIM modules and PAWS were procured. FY87 accomplishments under the Air Force's ENSCE program included the delivery, testing and evaluation of the PAWS and AIM. In late 1987, the Army cut ASAS funding by $484 million as part of the service's overall effort to cut costs. This resulted in a reduction of planned equipment acquisitions, a delay in full operational capability, and the retention of the early fielding of a limited capability system.

During 1989 the ICE software underwent development and integration, and successful acceptance testing and training was completed by April 1989.

On 10 January 1990, the Chief of Staff of the Army directed the ASAS program be restructured to field the system as quickly as possible with the minimum level of functionality acceptable to the user by converting Evolutionary Development RDT&E funds to Other Procurement Army funds. Key elements of the restructured program are the transition to Common Hardware Software equipment beginning in FY 1992 and increased Other Procurement Army funding through the year FY 2007.

In April 1990, the Air Force notified the JTFPO that the ENSCE program was being terminated due to budget constraints and the need to use hardware being provided in the upgrade of the Tactical Air Control System. No Air Force funding would be provided to JTFPO after FY 1990. Since the Air Force funding contributed significantly to the software development effort (30 percent of FY 1991 RDT&E), this decision resulted in a review of ASAS cost and schedule. By the end of 1990, the JTFPO was closed and the Project Office for ASAS was placed under the Army Program Executive Officer of Command and Control Systems.

Due to direction from Congress to build only the smaller modules, the IDP development was deferred to the block upgrade phase. The full capability ASAS production decision is now scheduled for February 1993 (moved back from January 1992).

A restructuring of ASAS is in the works with the focus on accelerating development of a limited-capability version of ASAS to the 1994 time-frame. The addition of special software, called the Artificial Intelligence Module Test Bed (also known as Hawkeye) is to increase the system's capability to combine intelligence from many sources. The result will be known as the ASAS Hybrid. It may delay the fielding of the Block 2 ASAS, which represents the "full capability" ASAS.

c. Program Costs

The ASAS program cost was re-baselined from the planning estimate to development estimate in 1986, resulting in a changes in the base-year dollars from FY 1984 to FY 1986 in the 1987 SAR. In only three years, from 1987 to 1990, the ASAS program has seen development cost growth of 79 percent. The increase was due to the program restructuring directed by Congress—design change in the PAWS, downsized modules to adapt to the battlefield environment, budget cuts, termination of Air Force funding, accelerated acquisition. In 1990 alone, development cost growth was 30 percent. Although the program is still in LPU, and full-scale production will not start until 1993, total production cost growth is 194 percent. Since the program's inception, the total procurement quantity was not reported until 1990 because quantities for ASAS/ENSCE

systems vary based on specific echelon or mission requirements (e.g., Heavy Division, Light Division, Corps, and Echelon-Above-Corps). The size variation is relative to the number and type of PAWS, FSIC, and AIM modules within the system and results in a considerable difference in cost. The quantities procured in each fiscal year consist of two or more systems of different configurations; therefore, a unit of measure was not defined for the ASAS/ENSCE. The ASAS program schedule summary is shown in Table II-19. Because overall program costs are classified, the table does not include a program cost summary.

Table II-19. ASAS/ENSCE Program Schedule Summary

	Development Estimate (12/84)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Dec-84	Dec-84	N/A
End Date (IOC)	Nov-87	Apr-89	N/A
Quantity	N/A	N/A	N/A
Production			
Start Date	Mar-87	Mar-87	Mar-87
End Date	Sep-89	Sep-06	Sep-06
Quantity	N/A	N/A	N/A
Program Status			
Development—Completed			
Production—3 years of data			

Note: N/A means not applicable.

d. Contract Information

Jet Propulsion Laboratory (JPL) is the prime contractor for the ASAS/ENSCE's RDT&E. Although JPL is the prime contractor, JTFPO does not have a contract with JPL for the ASAS effort. JPL is performing under a Task Order against a NASA contract. JPL's role for the ASAS/ENSCE baseline phase (development) is that of a Systems Engineering and Technical Direction contractor, which includes a significant number of project management functions normally attributed to a government program office such as technical integration and management functions associated with systems development, to include architectural design, RFP completion, competitive contracting for prototypes (JPL would let major contracts during this phase), acceptance testing, conducting government reviews and associated contract management of industrial contractors. JPL's role during the objective system phase (production) was that of a System Engineering/Technical Assistance contractor.

The program involves numerous contractors and subcontractors and two primary types of contracts: type "A" for communication and module integration and type "B" for intelligence systems. There also will be a type "C" for software integration. The baseline software involves over 1.5 million lines of code and a yet-to-be-determined amount of code for future expansion of capabilities. All contractors will report to JPL, which was designated by the Army to select a computer system and a subcontractor to design, develop and integrate a complete ASAS system [6].

e. Acquisition Initiatives

The only acquisition initiative applied to the ASAS/ENSCE program was prototyping.

9. M198 155mm Towed Howitzer

The M198 was originally developed as a successor to the M114 155mm howitzer in front-line units, and to meet the requirement for towed, medium artillery. In February 1988 the Secretary of Defense terminated the program to cut the budget. Production is dormant but can be resumed if warranted; the M198 is in service in the United States and several other countries.

a. System Description

The M198 is air transportable by CH-47C helicopter and provides increased range, improved reliability and maintainability over the earlier M114 and M114A1 howitzers. The M198 has twice the range of the older M114 and can fire a wide range of conventional ammunition rounds, as well as the Army's M712 Copperhead laser-guided projectile, nuclear projectiles, improved conventional munitions, and scatterable mines. Four major assemblies make up the M198:

1. The M39 carriage, consisting of the top and bottom carriages, cradle, and the equilibrator assembly. The spades are detachable. The M39 is manufactured by Consolidated Diesel Mobile Equipment.
2. The M45 recoil assembly, comprising two steel recoil cylinders and a recuperator cylinder. It is manufactured by Rock Island Arsenal, the prime contractor.
3. The M199 ordnance assembly, composed of the barrel, breech, and muzzle brake. This assembly is produced by Watervliet Arsenal.
4. The fire-control system, consisting of the M137 panoramic telescope, M18 gunner's quadrant, M138 elbow telescope and an M139 alignment device in

addition to lighting, leveling, and other components. Numax Electronics of Hauppauge, N.Y., is the contractor.

The M198 is too heavy to be air transported by the UH-60 Black Hawk helicopter. The Army wants a new carriage and trails that would lower the gross weight of the howitzer from 7,163 kg to no more than 4,083 kg. A new lightweight 155mm howitzer utilizing M198 components is being developed for use by the Army's light divisions. The development contract for this program was issued in December 1985.

b. Acquisition Background

Development of the M198 began in September 1968. A test rig was built to demonstrate that a lightweight towed 155mm howitzer could fire the increased range of ammunition with reasonable probability of stable dynamics and structural soundness. Design and fabrication of an advanced development prototype began in 1969 and firing trials in 1970.

Rock Island was responsible for the carriage and recoil mechanism, Frankford Arsenal for the fire control equipment, Watervliet Arsenal for the ordnance, and Picatinny Arsenal and the Harry Diamond Laboratory for the ammunition.

Engineering Development (ED) began in December 1970. The first two prototypes were delivered in April and May 1972 and were followed by eight further prototypes. An extensive firing test program was conducted on three ED prototypes to determine any weakness in the weapon design. Also, considerable component testing was performed. Six howitzers were built for DT/OT II testing. DT/OT II testing began in March 1975 and all phases except environmental tests were completed prior to the ASARC. Initial Production began at Rock Island Arsenal in December 1976 with the first production weapons being completed in July 1978. Production Validation Testing was completed in October 1979.

Since 1978 large numbers of M198s have been built for the home and export markets but there has been no US Army funding since FY 1982. It was planned to be funded again in FY 1989 through FY 1992 to complete reserve component fielding but this was stopped due to budget restriction. By 1988, about 1,800 M198s had been built, 1,000 of them for the U.S. Army and Marine Corps.

Rock Island Arsenal's integration and final assembly schedule was delayed due to a manpower shortage and to a deficiency in the ring gear bearing. The bearing was manufactured in accordance with drawings but did not contain proper tolerance specifications.

c. Program Costs

The M198 program schedule and cost summary are shown in Table II-20.

Table II-20. M198 155mm Towed Howitzer Program Schedule and Cost Summary

	Development Estimate (12/75)	Current Estimate (3/81)	Current Estimate for Development Estimate Quantity
Development			
Start Date	Dec-70	Dec-70	N/A
End Date (IOC)	May-77	Apr-79	N/A
Quantity	10	10	N/A
Cost	$30.9	$41.7	N/A
Production			
Start Date	May-75	Dec-76	Dec-76
End Date	Sep-81	Sep-82	Sep-82
Quantity	654	584	654
Cost	$80.2	$94.1	$103.6
Program Status			
Development—Completed			
Production—Completed			

Note: Costs are in millions of base-year 1965 dollars. N/A means not applicable.

d. Acquisition Initiatives

Two acquisition initiatives have been applied to the M198 155mm howitzer program, prototyping and multi-year procurement.

III. SHIPS AND RELATED NAVY PROGRAMS

Fifteen ship programs were added to our data base: three combat data systems, ten classes of surface vessels, and two classes of attack submarines. The programs are listed in Table III-1. The three combat data systems are being produced by two different companies. Nine different shipyards have been used to produce the ten classes of surface ships, and two different shipyards are being used to produce the two classes of submarines. Four of the ship classes are modifications of previous ship classes. Data for these programs were obtained from Selected Acquisition Reports and information supplied by the Navy Center for Cost Analysis, supplemented with information from References [8] and [9].

Table III-1. Ship Programs

Program	Class	Type	New/Mod	Quantity	Producers
AEGIS	—	Air defense system	New	65	General Electric (RCA)
AN/BSY-1	—	Submarine combat system	New	NA	IBM
AN/BSY-2	—	Submarine combat system	New	31	General Electric
SURTASS/T-AGOS	Stalwart	Ocean surveillance	New	18	Tacoma Boat Building, Halter Marine
CG-47	Ticonderoga	Surface combatant	Mod of DD-963	27	Bath Iron Works, Litton/Ingalls
DD-963	Spruance	Surface combatant	New	31	Litton/Ingalls
DDG-51	Arleigh Burke	Surface combatant	New	38	Bath Iron Works, Litton/Ingalls
FFG-7	Oliver Hazard Perry	Surface combatant	New	51	Bath Iron Works, Todd/Seattle, Todd/San Pedro
LHA-1	Tarawa	Amphibious warfare	New	5	Litton/Ingalls
LHD-1	Wasp	Amphibious warfare	Mod of LHA	6	Litton/Ingalls
LSD-41	Whidbey Island	Amphibious warfare	Mod of LSD-36	8	Lockheed, Avondale
LSD-41CV	Harpers Ferry	Amphibious warfare	Mod of LSD-41	6	Avondale
SSN-21	Seawolf	Attack submarine	New	9	General Dynamics/ Electric Boat, Newport News
SSN-688	Los Angeles	Attack submarine	New	62	General Dynamics/ Electric Boat, Newport News
TAO-187	Henry J. Kaiser	Replenishment oiler	New	18	Avondale, Penn Shpbldg/ Tampa Shpyd

Ten of the fifteen programs are still in production. The earliest program began full-scale development in 1968, started production in 1971, and is still in production. The dates each of the systems started development and production, along with the initial operational capability dates and projected production end dates, are shown in Table III-2.

Table III-2. Development and Production Start and End Dates for Ship Programs

Program	Class	FSD Start	Production Start	IOC	Production End
AEGIS	—	12/69	1/78	9/83	FY01
AN/BSY-1	—	9/83	N/A	3/90	N/A
AN/BSY-2	—	2/88	12/95	5/95	FY99
SURTASS/T-AGOS	Stalwart	10/74	5/77	8/83	FY87
CG-47	Ticonderoga	1/78	1/78	9/83	FY94
DD-963	Spruance	6/70	6/72	6/77	2/83
DDG-51	Arleigh Burke	12/83	10/86	2/92	FY01
FFG-7	Oliver Hazard Perry	12/83	10/86	2/92	FY01
LHA-1	Tarawa	4/69	1/71	5/77	FY81
LHD-1	Wasp	7/82	6/83	10/90	FY98
LSD-41	Whidbey Island	11/78	1/81	2/86	FY92
LSD-41CV	Harpers Ferry	12/87	11/89	10/90	FY99
SSN-21	Seawolf	6/85	6/88	5/95	FY99
SSN-688	Los Angeles	11/68	1/71	11/76	FY97
TAO-187	Henry J. Kaiser	12/81	11/82	2/87	FY94

Note: N/A means that data were either not available or insufficient.

Current estimates of how much the ship production costs would be for the quantities originally planned for at the time of the development estimates, were calculated using price improvement curves. (See Section III of Volume I for a detailed description.) Development or current estimates of production costs for the air defense and submarine combat systems could not be determined from the SARs. Any production cost data shown in the SARs for those programs are for support equipment. The actual production costs for those programs are included in the production costs for the ships in which they are installed, and those costs are not broken out separately in the SARs for the ships.

Information on the acquisition program initiatives applied to each of the programs was obtained from a questionnaire submitted to the Navy program managers. The program effectiveness measures were then compared on the basis of the particular acquisition program initiatives applied to determine the initiatives' effectiveness. The comparisons were made using statistical tests to determine whether there was any significant difference between the sample of programs to which a particular acquisition initiative was applied and the sample of programs to which the initiative was not applied. A discussion of the

program outcome measures and how they were affected by the acquisition initiatives applied follows. After that, we provide a brief description of each of the programs.

A. SHIP PROGRAM OUTCOMES

1. Distinguishing Features of Ship Acquisition Programs

Estimates of development, military construction, and production costs for each of the fifteen ship programs are shown in Table III-3. These estimates are based on data from the December 1989 SARs converted to base-year 1991 constant dollars.

There are several features which distinguish the ship acquisition programs from the other acquisition programs. The first is that there are generally low numbers of units produced with very high unit costs. The greatest quantity to be produced in any of the ship programs is 65, and the median for the fourteen programs for which quantity data are available is 29. The median of the average unit production costs for the ship programs is over $530 million, and the highest of the average unit production costs is over $1.45 billion.

The second distinguishing feature of the ship acquisition programs is that development costs are a low proportion of total program costs. Across the twelve programs for which total cost data are available, the mean percentage of development costs to total costs is 3.3 percent, and the median is an even lower, 1.6 percent. There are two basic reasons for these low percentages. The first is that much of what the rest of the defense industry refers to as development costs are included in Navy production costs; in particular, the costs of detailed design are typically funded by Ship Construction Navy appropriations rather than Navy development appropriations. The second reason is that the production costs for the ship programs include the costs not only of the ship and its associated propulsion (except for certain nuclear powerplant costs) and auxiliary equipment, but also the costs of the combat systems with which the ship is equipped.

The third distinguishing feature of the ship acquisition programs is that they have been taking place at a time of great overcapacity in the U.S. shipbuilding industry. The numbers of ships (merchant ships greater than 1,000 gross tons, and Navy ships) delivered by U.S. shipyards since 1949 are shown in Figure III-1 based on data from References [10] and [11]. There has been no trend in the numbers of ships produced by U.S. shipyards for both the U.S. Navy and foreign navies.

Table III-3. Current Estimates of Ship Program Costs
(Millions of FY 1991 Dollars)

Program	Production Units	Development Cost	Production Cost	Production Average Unit Cost	Military Construction Cost	Total Program Cost
AEGIS	65	1,697.0	N/A	N/A	0.0	N/A
AN/BSY-1	N/A	1,450.1	N/A	N/A	0.0	N/A
AN/BSY-2	31	2,181.1	N/A	N/A	0.0	N/A
SURTASS/T-AGOS Stalwart Class	18	258.5	924.3	51.4	0.0	1,182.8
CG-47 Ticonderoga Class	27	133.4	30,670.2	1,135.9	28.2	30,831.8
DD-963 Spruance Class	31	129.0	10,445.0	336.9	0.0	10,574.0
DDG-51 Arleigh Burke Class	38	1,446.3	26,359.2	693.7	29.7	27,835.1
FFG-7 Oliver Hazard Perry Class	51	58.3	1,418.4	27.8	0.0	1,476.8
LHA-1 Tarawa Class	5	79.4	4,698.5	939.7	0.0	4,777.9
LHD-1 Wasp Class	6	59.9	6,813.3	1,135.5	0.0	6,873.1
LSD-41 Whidbey Island Class	8	75.5	3,276.8	409.6	0.0	3,352.3
LSD-41CV Harpers Ferry Class	6	14.6	1,513.9	252.3	0.0	1,528.5
SSN-21 Seawolf Class	9	2,871.7	13,130.2	1,458.9	77.1	16,079.0
SSN-688 Los Angeles Class	62	79.2	40,544.6	653.9	66.0	40,689.8
TAO-187 Henry J. Kaiser Class	18	19.5	3,097.3	172.1	0.0	3,116.8

Note: N/A means that data were either not available or insufficient.

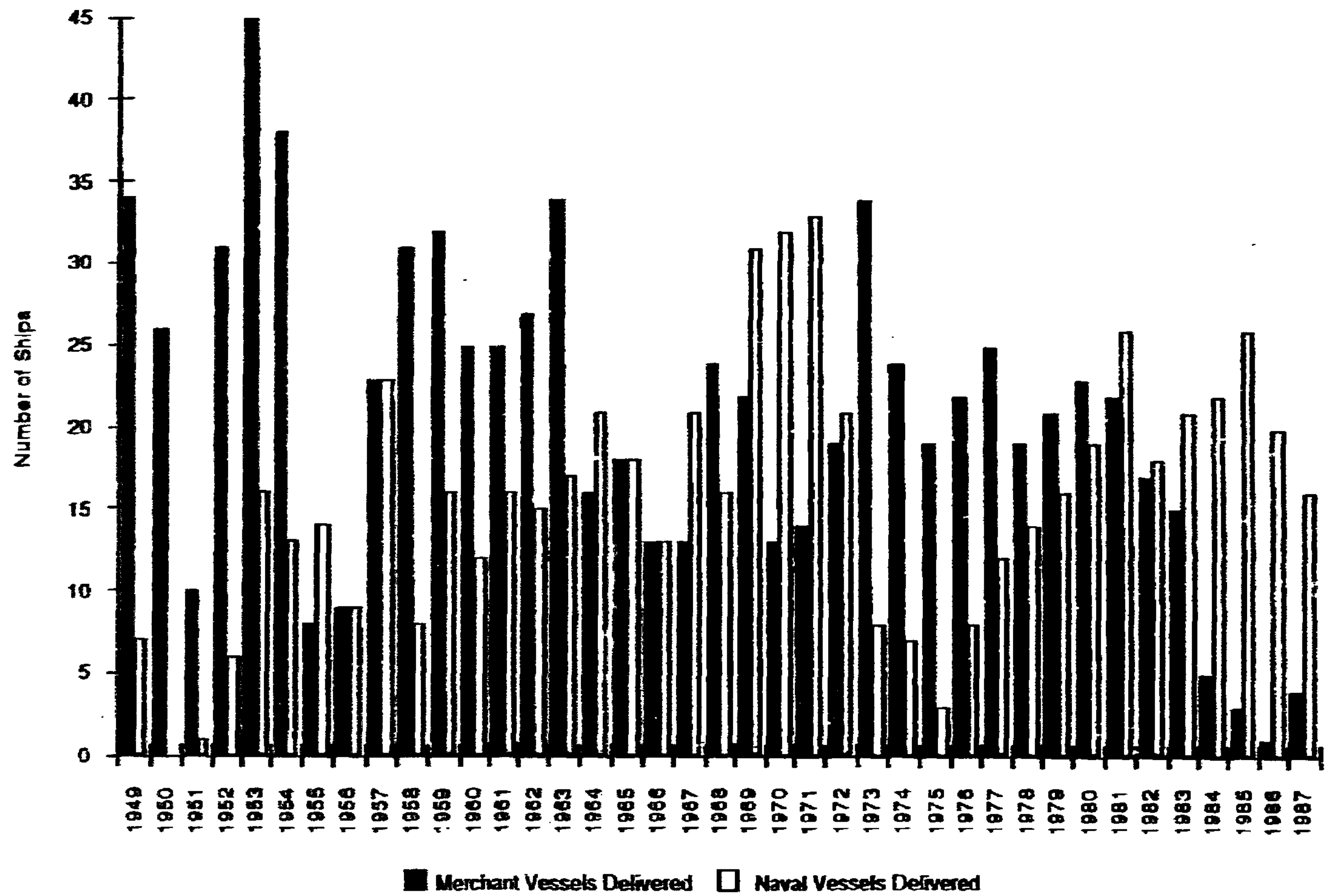


Figure III-1. Ships Delivered by U.S. Shipyards, 1949-1987

However, the numbers of merchant ships over 1,000 gross tons produced annually by U.S. shipyards for both domestic and foreign ship owners have declined since 1949, because of cheaper operating costs for foreign flag shipping, and a recurrent boom and bust cycle of overcapacity in available merchant shipping tonnage world-wide. Until recently, costs of building and overhauling ships have also been much lower abroad, but that cost differential has been reduced by the decline in the value of the U.S. dollar. There are few alternative products for U.S. shipyards to produce, other than off-shore oil platforms, and structural and equipment assemblies for building construction and industrial use. As a result, there has been short-run pressure on shipyards to compete with lower prices. In the longer run, shipyards will go out of business, either voluntarily or involuntarily as in the cases of Lockheed Shipbuilding and Construction, Pennsylvania Shipbuilding, and Todd Shipyards, among others. Less overcapacity, and a smaller number of competitors in the future may result in higher production costs for naval ships.

The fourth distinguishing feature of the ship acquisition programs is the high cost of adapting equipment to operate in the stringent marine operating environment. The two primary environmental problems are corrosion from saltwater and humid sea air, and the pounding and shocks to the hull of the ship as it moves through the seas. As a result, non-maritime combat equipment is rarely adapted to maritime use, though the RIM-7H Sea Sparrow surface-to-air missile and the BGM-109 Tomahawk cruise missile can be used at sea and ashore. Further, the costs of combat equipment developed for the maritime environment inhibits its use elsewhere. As a result, there is an incentive to use expensive combat systems developed for a maritime environment across as many Navy programs as possible. This economizes on both development and production costs. It also implies that cost growth should be lower for ship programs because of the extensive use of combat systems across multiple ship classes. Examples of this commonality for the ships programs in this analysis are shown in Table III-4.

2. Outcomes of Ship Acquisition Programs

Acquisition program outcomes for the fifteen ship programs are shown in Table III-5 and in Figure III-2. Unlike the other acquisition programs in the study, development quantity growth is not included among the acquisition measures for the ship programs, because there was no development quantity growth for any of the ship programs, and there were no development quantities for most of them.

Table III-4. Commonality of Subsystems Between Ship Classes

Subsystems	Type	Manufacturer	CG-47	DD-963	DDG-51	FFG-7	LHA-1	LHD-1	LSD-41	SSN-21	SSN-688
LM 2500	Gas Turbine	General Electric	X	X	X	X	—	—	—	—	—
AN/BQQ-5D	Hull Mounted Sonar	Sperry	—	—	—	—	—	—	—	X	X
AN/SLQ-32	ECM System	Raytheon	X	X	X	X	X	X	X	—	—
AN/SPG-60	Gun Tracking Radar	Lockheed	—	X	—	—	X	—	—	—	—
AN/SPG-62	Missile Fire Control Radar	Raytheon/RCA	X	—	X	—	—	—	—	—	—
AN/SPQ-9I	Fire Control Radar	Lockheed	X	—	—	—	X	—	—	—	—
AN/SPS-40	Air Search Radar	Lockheed	—	X	—	—	X	—	—	—	—
AN/SPS-49	Air Search Radar	Raytheon	X	X	—	X	—	X	X	—	—
AN/SPS-52	Air Search Radar	Hughes	—	—	—	—	X	X	—	—	—
AN/SPS-55	Surface Search Radar	ISC Cardion	X	X	—	X	—	—	—	—	—
AN/SPS-64	Navigation Radar	Raytheon	X	X	X	—	X	X	X	—	—
AN/SPS-67	Surface Search Radar	Norden	—	—	X	—	X	X	X	—	—
AN/SQQ-89	Towed Array Sonar	Gould	X	X	X	X	—	—	—	—	—
AN/SQS-53B/C	Hull Mounted Sonar	General Electric/Hughes	X	X	—	—	—	—	—	—	—
AN/SQS-53C	Hull Mounted Sonar	General Electric	X	X	—	X	—	—	—	—	—
MK 29	Missile Launch System	Raytheon	—	X	—	—	—	X	—	—	—
MK 32	Torpedo Launch System	—	X	X	—	X	—	—	—	—	—
MK 41	Missile Launch System	FMC	X	X	X	—	—	—	—	—	—
MK 15	Phalanx Gun System	General Dynamics	X	X	X	X	X	X	X	—	—
5"/54 MK 45	Gun	FMC	X	X	X	—	X	—	—	—	—
MK 7 AEGIS	Weapon Control System	General Electric	X	—	X	—	—	—	—	—	—
MK 116	Underwater Fire Control System	Singer Librascope	X	X	—	—	—	—	—	—	—
TB-23	Towed Sonar Array	Martin Marietta	—	—	—	—	—	—	—	X	X
	Navy Tactical Data System	Hughes	X	X	X	X	—	—	—	—	—

Table III-5. Outcome Measures for Ship Programs (Percent)

Program	Development Schedule Growth	Development Cost Growth	Production Cost Growth	Production Quantity Growth	Production Schedule Growth	Stretch	Military Construction Cost Growth	Total Program Cost Growth
AEGIS	-4	28	N/A	N/A	N/A	N/A	N/A	N/A
AN/BSY-1	0	41	N/A	N/A	N/A	N/A	N/A	N/A
AN/BSY-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SURTASS/T-AGOS Stalwart Class	38	78	63	50	54	3	N/A	68
CG-47 Ticonderoga Class	-8	23	-6	69	14	-33	5	-6
DD-963 Spruance Class	40	6	23	3	78	72	N/A	23
DDG-51 Arleigh Burke Class	20	40	-6	322	111	-50	-1	-1
FFG-7 Oliver Hazard Perry Class	15	40	59	2	83	80	N/A	59
LHA-1 Tarawa Class	56	0	58	-44	80	225	N/A	57
LHD-1 Wasp Class	6	9	-6	100	49	-22	N/A	-6
LSD-41 Whidbey Island Class	4	9	-8	-33	0	50	N/A	-8
LSD-41CV Harpers Ferry Class	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SSN-21 Seawolf Class	4	35	N/A	N/A	N/A	N/A	-25	N/A
SSN-688 Los Angeles Class	66	-8	-1	520	60	-74	22	-1
TAO-187 Henry J. Kaiser Class	5	-3	-8	6	2	-3	N/A	-8
Mean	18.6	22.9	16.8	99.4	53.1	24.7	0.3	17.7
Low	-8.0	-7.7	-8.3	-44.4	0.0	-74.2	-25.5	-8.1
High	65.5	78.1	63.2	520.0	110.6	224.5	22.2	67.5

Note: N/A means that data were either not available or insufficient.

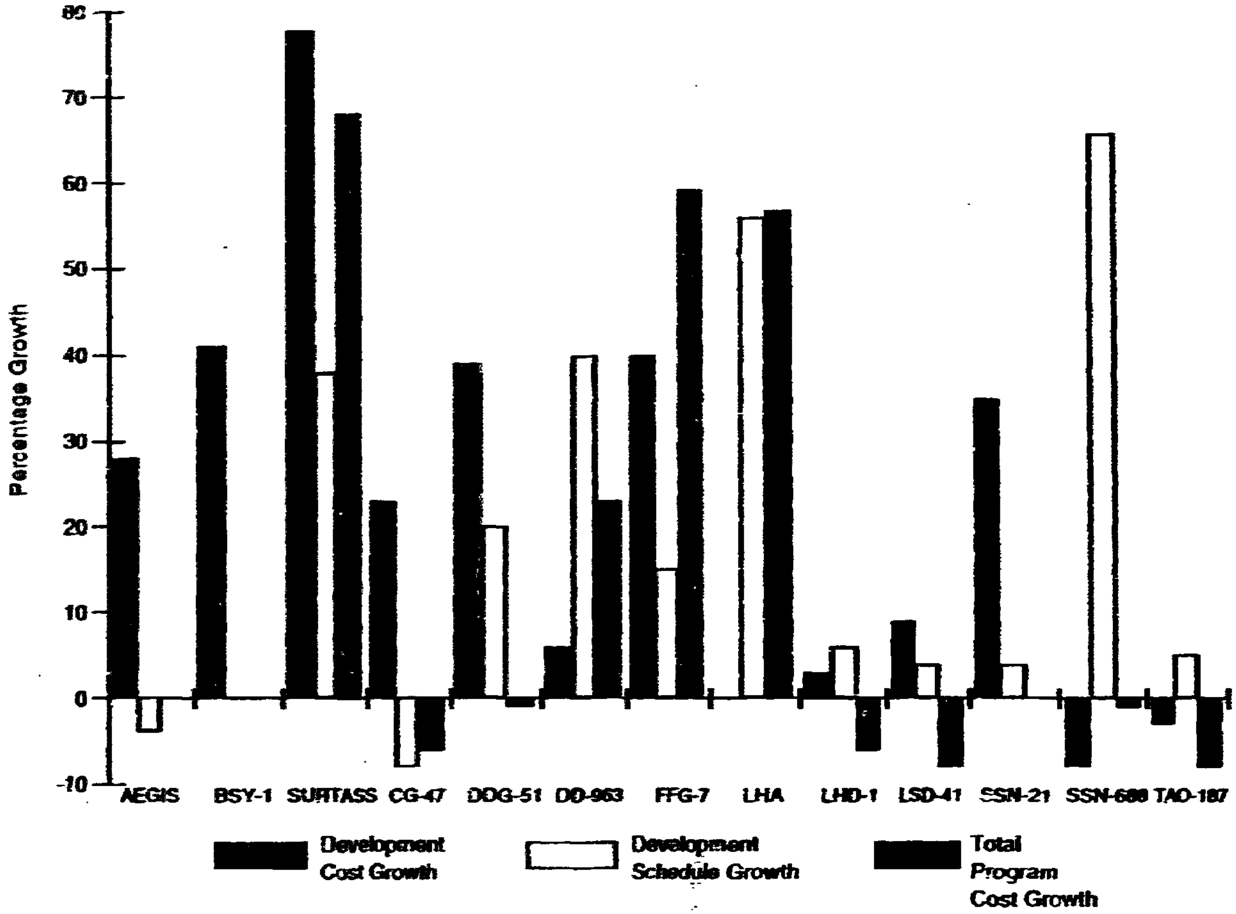


Figure III-2. Outcome Measures for Ships and Related Navy Programs

These outcome measures appear to be quite different from the outcome measures for the other acquisition programs in the study, as shown in Table III-6. Total cost growth and production cost growth are much less for the ship programs, while development cost growth is somewhat less for the ship programs. Development schedule growth is much less for the ship programs, but production schedule growth is somewhat less. Production quantity growth is much higher for the Navy programs, primarily because the Navy initial estimates of production quantities are for minimal numbers.

The only ship acquisition program outcome measure to be related to when FSD was started is development schedule growth. Development schedule growth is generally higher for the earlier programs and lower for the later programs, and this relationship is statistically significant at the 2.5-percent level.

For the ship acquisition programs, development schedule growth is not related to either development cost growth or production cost growth. On average, production cost growth is higher for programs with higher development schedule growth, but the relationship is not statistically significant.

However, total program cost growth is higher, on average, for programs with higher development cost growth, and that relationship is statistically significant at the 10-percent level. Problems which increase the proportionately small development costs (small in relation to total costs) are likely to carry over into the detailed design efforts that are funded out of production costs. Production cost growth was generally less for programs that were modifications of previous ship programs, and this relationship was statistically significant at the 4-percent level. The same result had been observed for the other programs in the database.

3. Effects of Acquisition Initiatives on Ship Program Outcome Measures

The major initiatives applied to the ship programs are shown in Table III-7. We examined Pearson correlation coefficients of the 1/0 variables representing the acquisition initiatives with the outcome measures. There were four significant correlations:

- Total package procurement is related to higher production cost growth and total program cost growth (.03). This confirms findings in the rest of the database. Total package procurement was also related to higher development schedule growth (.02).
- Prototyping is related to higher development cost growth (.03), contrary to expectations. Perhaps prototyping is more difficult in ship programs. In some sense, the lead ship serves as a prototype—production of the lead ship is

Table III-6. Cost and Schedule Outcomes for Ship Programs and Other Equipment Types

Program By Equipment Type	Development Time		Production Time		Development Schedule Growth		Production Schedule Growth		Development Cost Growth		Production Cost Growth		Total Program Cost Growth	
	N	Avg. (mos.)	N	Avg. (mos.)	N	Avg. (%)	N	Avg. (%)	N	Avg. (%)	N	Avg. (%)	N	Avg. (%)
Ships and Related	14	90	10	166	13	17	10	53	13	23	10	17	10	18
Ground Combat	9	82	9	97	9	50	7	-16	9	52	7	147	7	136
Aircraft	27	72	23	135	27	14	23	70	27	33	25	27	25	27
Tactical Munitions	30	82	26	119	30	50	26	70	30	56	26	79	26	68
Other	19	92	13	119	21	41	11	48	21	55	14	60	14	42

Note: Some programs identified as tactical munitions in Volume I of this paper are considered to be ground combat programs in this volume; consequently, averages may vary.

Table III-7. Acquisition Initiatives Applied in Ship and Related Navy Programs

Program	Prototype	Dual-Sourcing FSD	Dual-Sourcing Production	DTC	MYP	FPD	TPP	Contract Incentives FSD	Contract Incentives Production
AEGIS	1	1	0	0	0	0	0	1	1
AN/BSY-1	1	0	0	1	0	0	0	1	1
AN/BSY-2	1	1	0	1	0	0	0	1	1
SURTASS-T/AGOS	1	1	1	1	1	0	1	0	1
CG-47	1	0	1	0	0	0	0	1	1
DD-963	1	0	0	0	0	0	1	1	1
DDG-51	0	0	1	1	0	0	0	N/A	1
FFG-7	1	1	1	1	0	0	0	1	1
LHA-1	0	0	0	N/A	0	0	1	1	1
LHD-1	0	0	1	1	0	0	0	1	1
LSD-41	0	1	1	1	0	0	0	1	1
LSD-41 Cargo	0	0	1	1	1	0	0	0	1
SSN-21	1	0	1	0	0	0	0	0	1
SSN-688	0	0	1	N/A	1	0	0	N/A	1
TAO-187	0	0	1	0	0	1	0	1	1

Note: N/A means that data were either not available or insufficient.

where problem-solving takes place. Programs made extensive use of prototyping at the subsystem level. However, it may be that we are not seeing benefits because non-prototyped programs used an even more cost-effective strategy—using common, already-developed subsystems. (See Table III-4.)

- Incentive contracts in FSD are related to lower development cost growth (.02). This is consistent with findings elsewhere in the report.

It is surprising that we do not see a statistically significant effect of dual-sourcing, a major Navy initiative, particularly in the 1980s. During that time, dual-sourcing was virtually universal for the programs in this group. We have only two programs with production data that were *not* dual-sourced—the LHA and the DD-963. Their production cost growth is higher than the dual-sourced programs.

The detailed case studies that follow also address other less prominent acquisition initiatives. Only one had a statistically significant effect in the aggregate: Development schedule growth was significantly less for programs that had independent testing (.06).

B. CASE STUDIES

1. AEGIS Air Defense System

The AEGIS air defense system was developed for defense of surface combatants against enemy aircraft and cruise missiles. It is being installed on the CG-47 Ticonderoga class guided missile cruisers and the DDG-51 Arleigh Burke class guided missile destroyers, and is being sold to Japan. The system provides weapons control for the General Dynamics RIM-66C Standard Missile 2, the General Dynamics Standard Missile 1, the Honeywell RUR-51 antisubmarine rocket, and the McDonnell Douglas RGM-84 Harpoon cruise missile. The system includes:

- AN/SPY-1 multi-function phased array radar;
- FCS MK 99 target illuminator radar;
- Command and Decision System MK 1 for evaluation of targets and selection of weapons; the Weapon Control System MK 1 for weapons control; and
- Operational Readiness Test System MK 1.

AEGIS is the first three-dimensional, phased-array radar that can be mounted on a ship smaller than an aircraft carrier or large cruiser. The phased-array architecture allows the radar beam to be aimed in both the horizontal and vertical planes. Predecessor conventional air defense systems generally required separate air-search and height-finder

radar, and were not capable of tracking as many targets, nor could they react as rapidly to multiple threats.

Engineering development was started in December 1969, by the RCA Corporation Government Systems Division, Moorestown, New Jersey. Advanced development of the SPY-1 radar had started earlier, in August 1964, with a prototype following in 1968. An engineering development model was completed in July 1972, and was tested at the land-based site in Moorestown through December 1972. A ship-based model was tested at sea over a period of eleven years on the Norton Sound (AVM-1). General Electric, which purchased RCA, is the prime production contractor. The Milestone III production authorization was in January 1978, thirty-two months later than the development estimate of May 1975. The initial operational capability was in September 1983, six months ahead of schedule. Actual development costs were 27.9 percent higher than the estimate made at the start of engineering development.

Production cost data for the AEGIS are not available in the SARs. The production costs for AEGIS are included in the production costs for the CG-47 and DDG-51 classes, but are not separately identified in the SARs for those classes. The schedule and cost data for AEGIS are summarized in Table III-8.

The following acquisition initiatives have been applied to the AEGIS procurement:

- An advanced development phase, beginning in August 1964, with a prototype in October 1968, of one of the major subsystems, the SPY-1 radar;
- Should cost analysis in March 1987, and could cost analysis in December 1985;
- Full-scale development competition for the SPY-1 radar subsystem, in December 1969;
- Independent cost evaluation in March 1987;
- Independent testing in July 1989 and November 1990;
- Dual-sourcing of the SPY-1 radar, fire control system, and weapon control system;
- Cost plus incentive fee full-scale development contract, with an incentive based on a cost target—costs are offset by fee losses until costs exceed 144 percent of the target, after which the contractor absorbs 25 percent of all losses; and
- Firm fixed-price and fixed-price-incentive contracts for production.

Table III-8. AEGIS Program Schedule and Cost Summary

	Development Estimate (12/70)	Current Estimate (12/79)
Development		
Start Date	12/69	12/69
End Date (IOC)	3/84	9/83
Quantity	1	1
Cost	$394.2	$504.0
Production		
Start Date	5/75	1/78
End Date	FY93	FY01
Quantity	27	65
Program Status		
Development—Completed		
Production—No data available; costs included in CG-47 and DDG-51 costs, not broken out separately		

Note: Costs are in millions of base-year 1970 dollars.

AEGIS was not subjected to multi-year procurement, total package procurement, or, at the system level, to full-scale development competition, dual-sourcing or other production competition, or warranty.

2. AN/BSY-1 Submarine Combat System

The AN/BSY-1 submarine combat system is being produced for use in the SSN-688 Los Angeles class attack submarines, hull numbers 751 through 773. It and the AN/BSY-2 are follow-on programs to the restructured SUBACS system, which was being developed by IBM for use in both the SSN-688 and the SSN-21 Seawolf class attack submarines. The Mission Element Needs Statement (MENS) was approved for the SUBACS program in November 1980 and the program was initiated in 1981, followed by concept definition in March 1982 and the start of full-scale development in December 1983. Because of problems with the technology, the program was split in June 1985 into the SUBACS Basic system, which subsequently became AN/BSY-1, and the FY 1989 submarine combat system, which subsequently became the AN/BSY-2. The distributed system data bus architecture was eliminated from the AN/BSY-1 and replaced with a lower risk architecture using AN/UYK-43 computers. IBM continued as the prime contractor for AN/BSY-1, but General Electric became the prime contractor for AN/BSY-2.

The system is used for antisubmarine warfare, antisurface warfare, attacks against targets ashore, and mine warfare; the system also supports the submarine special warfare, ocean surveillance, intelligence, and electronic warfare missions. It orients the submarine's sensors and weapon control systems, and processes information from the submarine's active and passive sonars and other sensors to provide targeting and weapons control information for the employment of torpedoes, cruise missiles, and mines. It includes a mine and ice detection and avoidance capability.

The full-scale development contract for SUBACS Basic was awarded to IBM in December 1983. There was no development quantity; an engineering development model and land based test site were deleted for cost reasons. First delivery, to SSN-751, was originally scheduled for June 1988, but took place fourteen months earlier. There is significant concurrence between the development and production schedules; eight systems will be delivered before the start of Technical/Operational Evaluation, and fifteen will be delivered before completion of Technical/Operational Evaluation.

The approved program development cost estimate of $2,027.5 million 1984 dollars was for the SUBACS system before the AN/BSY-2 was separated from the AN/BSY-1. When those two programs were separated, the development estimate for the AN/BSY-1 was reduced by $866.5 million 1984 dollars, to $1,160.0 million 1984 dollars. A separate development cost estimate of $1,566.2 million 1986 dollars was approved for AN/BSY-2. The current estimate of development cost for AN/BSY-1 of $1,137.9 million 1984 dollars shows a 2-percent decrease over the adjusted original estimate.

Production cost data for the AN/BSY-1 are not available in the SARs. The production costs for AN/BSY-1 are included in the production costs for the SSN-688 Los Angeles class submarines, but are not separately identified in the SARs for that class. The procurement costs shown in the SARs are for support equipment and trainers only. The schedule and cost data for AN/BSY-1 are summarized in Table III-9.

The turmoil in the two programs makes estimating cost growth a real challenge. Nevertheless, it is possible to sort out the true cost growth.

The original development estimate of $2,972.4 million 1984 dollars for the AN/BSY-1 development included the AN/BSY-2 development as well. As previously indicated, in 1986 the Navy separated the two programs and provided a separate development estimate for the AN/BSY-2 [12].

Since the original development estimate treated the subsystems as one program, we have combined the current estimates for the AN/BSY-1 and the AN/BSY-2. This yields a

current estimate of $2,849.4 million 1984 dollars, and development cost growth of 41 percent. There is insufficient production experience to calculate a production cost growth.

Table III-9. AN/BSY-1 and AN/BSY-2 Program Schedule and Cost Summary

	AN/BSY-1		Combined
	Development Estimate (12/83)	Current Estimate (12/89)	AN/BSY-1/-2 Estimate (12/89)
Development			
Start Date	9/83	9/83	9/83
End Date (IOC)	3/90	3/90	3/90
Quantity	0	0	0
Cost	$2,027.5	$1,137.9	$2,849.4
Production			
Start Date	N/A	N/A	12/95
End Date	N/A	N/A	FY99
Quantity	N/A	N/A	31
Cost	$944.9	N/A	N/A
Total Program Cost	$2,972.4	N/A	N/A
Average Unit Cost			
Production	N/A	N/A	N/A
Total Program	N/A	N/A	N/A
Program Status			
Development—7 years of data			
Production—0 years of data			

Note: N/A means that data were either not available or insufficient. Costs are in millions of base-year 1984 dollars.

The following acquisition initiatives have been applied to the AN/BSY-1 procurement:

- Competitive advanced development, with prototypes, was done for several of the subsystems;
- Several of the subsystems, and some of the software, were modifications of previously developed subsystems and software;
- Design-to-cost was implemented in 1985;
- Independent cost evaluations were conducted in 1983, 1985, and 1988;
- Several of the components were either dual-sourced or competitively produced;
- Development was initially under a cost plus award fee contract, and subsequently under cost plus incentive fee contract with cap contracts; and

- Production was under fixed-price incentive contracts during FY 1985–1987, and under firm fixed-price contracts since.

AN/BSY-1 was not subjected to multi-year procurement, or to full-scale development competition.

3. AN/BSY-2 Submarine Combat System

The AN/BSY-2 submarine combat system is being produced for use in the SSN-688 Los Angeles class and SSN-21 Seawolf attack submarines. It and the AN/BSY-1 are follow-on programs to the restructured SUBACS. The combined program was initiated in 1981, followed by concept definition in March 1982, and the start of full-scale development by IBM in December 1983. Because of problems with the technology, the program was split in June 1985 into the SUBACS Basic system, which subsequently became AN/BSY-1, and the FY89 submarine combat system, which subsequently became the AN/BSY-2. The distributed system data bus architecture that was eliminated from the AN/BSY-1 was retained for the AN/BSY-2. At the time that the AN/BSY-2 program was separated from the AN/BSY-1 program, fixed price system design definition contracts were awarded to the RCA Missile and Surface Radar Division (subsequently acquired by General Electric), and the IBM Federal Systems Division. After Milestone I in December 1986, both contractors replied to an RFP for a sustaining engineering contract, which was awarded to General Electric in December 1987.

The system is used for antisubmarine warfare, antisurface warfare, attacks against targets ashore, and mine warfare; the system also supports the submarine special warfare, ocean surveillance, intelligence, and electronic warfare missions. It orients the submarine's sensors and weapons control systems, and processes information from the submarine's active and passive sonars and other sensors to provide targeting and weapons control information for the employment of torpedoes, cruise missiles, and mines. It includes a mine and ice detection and avoidance capability. The system is highly software intensive.

The full-scale development contract was awarded in March 1988. As of the December 1989 SAR, low-rate initial production was scheduled to start late in 1989, and the initial operational capability was estimated for March 1990, with no slippage currently expected. Development cost growth was expected to exceed the approved AN/BSY-2 baseline estimate by 16 percent. How much, if any, of the actual development costs were buried in the SUBACS program cannot be determined from the SARs. The total procurement costs shown in the SARs are for system support equipment; they do not include the production costs for the systems to be installed in the SSN-688 or SSN-21

attack submarines. The costs for the systems to be installed in the submarines are included in the production costs in the SARs for those two submarine classes, but are not separately identified from the other production costs. As a result, no development estimate of production costs is available for the AN/BSY-2 system. However, annual total production costs and quantities are available from the SARs for the AN/BSY-2, allowing calculation of a current estimate of total production costs for the production quantity estimate made at the start of development. The schedule and cost information as given in the SARs for the AN/BSY-2 is summarized in Table III-10, but our estimate of cost growth is for the combined program, as shown in Table III-9.

Table III-10. AN/BSY-2 Program Schedule and Cost Summary

	Development Estimate (12/86)	Current Estimate (12/89)
Development		
Start Date	11/87	11/87
End Date (IOC)	7/95	5/95
Quantity	0	0
Cost	$1,566.2	$1,818.6
Production		
Start Date	12/95	12/95
End Date	FY99	FY99
Quantity	12	31
Cost	N/A	N/A
Support Equipment Cost	$893.9	$742.3
Total Program Cost	N/A	N/A
Average Unit Cost		
Production	N/A	N/A
Total Program	N/A	N/A
Program Status		
Development—4 years of data		
Production—1 year of data		

Note: N/A means that data were either not available or insufficient. Costs are in millions of base-year 1986 dollars.

The following acquisition initiatives have been applied to the AN/BSY-2 procurement:

- Competitive advanced development, with prototypes of subsystems, during fiscal years 1986-87;
- System prototype, in fiscal year 1988;
- The HFA sonar subsystem is a modification of a previously developed sonar;

- Design-to-cost was applied in fiscal year 1986, and should cost was applied in fiscal year 1987;
- Independent cost estimates were made in 1988 and 1990;
- Acquisition program streamlining was applied in fiscal years 1986-7;
- The contract for the production of the team trainer subsystem was awarded competitively; and
- Fixed-price incentive fee contracts were used for both full-scale development and production.

The AN/BSY-2 was not subjected to multi-year procurement, or to full-scale development competition.

4. SURTASS/T-AGOS-1 Stalwart Class

The SURTASS/T-AGOS-1 system consists of VQQ-2 Surveillance Towed Array Sound System (SURTASS) mounted on T-AGOS-1 Stalwart class ships. The VQQ-2 SURTASS subsystem is being purchased by Japan. The system is used for detecting submarines in oceanic areas where fixed underwater arrays are not available. The array is reeled out from the stern of the ship to a depth below the convergence layer, and towed at a speed of approximately 3 knots. Signals from the sensors on the array are transmitted back up the array to the ship, where they are transmitted via satellite to a shore-based processing facility. The ship design was modified from the design of a commercial off-shore oil-drilling rig support ship, with twin shafts driven by two 1,600-horsepower electric motors drawing power from four Caterpillar 398 diesel generators. Diesel-electric power was chosen to minimize the amount of own-ship's noise during surveillance operations, but also provides enough power to allow transit speeds of up to 16 knots. A 550-horsepower bow thruster is provided for maneuvering.

Development started in October 1974, and according to the latest available SAR (December 1980), initial operational capability was to have been attained in August 1983 with a slippage of two months. A prototype of the towed array was built and tested on a Navy research ship operated by the University of Hawaii. Numerous technical problems in developing the towed array are reflected in a development cost growth of 78 percent over the approved estimate. As of the last available SAR, production was to start in January 1981, 44 months behind the date estimated at the start of development. A multi-year production contract for the first twelve ships was awarded to Tacoma Boat, which went bankrupt before ships 9 through 12 were completed. Halter Marine was subsequently awarded a contract for ships 13 through 18. Production costs for the quantity estimated at

the start of development were 63 percent greater than the cost estimate made at the start of development. The production costs for the quantity estimated at the start of development were calculated from the current estimate of production costs using an assumed 90 percent cost improvement curve, because no annual quantities were shown in the SARs which could be used for directly estimating the first unit cost and slope of the price improvement curve. Development and cost information for the SURTASS/T-AGOS-1 are summarized in Table III-11.

Table III-11. SURTASS/T-AGOS Stalwart Class Program Schedule and Cost Summary

	Development Estimate (12/75)	Current Estimate (12/80)	Current Estimate for Development Estimate Quantity
Development			
Start Date	10/74	10/74	N/A
End Date (IOC)	3/81	8/83	N/A
Quantity	1	1	N/A
Cost	$59.4	$105.8	N/A
Production			
Start Date	5/77	1/81	1/81
End Date	FY81	FY87	FY87
Quantity	12	18	12
Cost	$146.5	$337.2	$239.1
Total Program Cost	$205.9	$443.0	$344.9
Average Unit Cost			
Production	$12.2	$18.7	$13.3
Total Program	$17.2	$24.6	$19.2
Program Status			
Development—Completed			
Production—Completed			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1975 dollars.

Because of problems with the sea-keeping characteristics of the T-AGOS-1 during 3-knot towing operations in heavy seas, a twin-hulled SWATH design is being built by McDermott Marine for four ships in the T-AGOS-19 Victorious class.

The following acquisition initiatives have been applied to the SURTASS/T-AGOS procurement:

- A prototype of the VQQ-2 SURTASS was developed and tested—but no prototype of the ship, which could have been a charter of a commercial vessel, was tested to see if the sea-keeping characteristics were satisfactory in heavy seas;

- There was competitive full-scale development at the system level between four companies during 1974-5;
- Design-to-cost was applied;
- An independent cost estimate was made in 1974;
- Multi-year procurement was applied to the development contract during 1976-80;
- A total package procurement contract was awarded for the production of the first twelve ships in 1980, but this was changed to a cost plus fixed fee for 1981-90; and
- Production of the VQQ-2 was dual-sourced, and a firm fixed-price production contract for ships 13 through 19 was competitively awarded.

5. CG-47 Ticonderoga Class

The CG-47 Ticonderoga class cruisers perform antiair, antisubmarine, and antisurface warfare, and strikes against surface targets, as part of an aircraft carrier or surface task force. It is built by Bath Iron Works and the Ingalls Shipbuilding Division of Litton Industries. The ship is a modification of the DD-963 Spruance class destroyer, with the addition of the AEGIS air defense system and different armament. Similar to the DD-963 class, the CG-47 class has four General Electric LM2500 gas turbines on two shafts with controllable reversible pitch propellers.

The CG-47 is equipped with two FMC MK 26 MOD 5 missile launch systems on hulls 47 through 51, and two FMC MK 41 vertical launch systems on subsequent hulls. The launch systems are for firing the General Dynamics RIM-66 Standard Missile 2-Medium Range for antiair warfare, Honeywell RUR-5A antisubmarine rocket for antisubmarine warfare, McDonnell Douglas RGM-84 Harpoon missile for attacks against surface targets, and General Dynamics BGM-109 Tomahawk missile for attacks against surface and land targets.

For antiair warfare, the CG-47 class is equipped with the following:

- General Electric RCA Government Systems Division MK 7 MOD 3 AEGIS weapon system, with General Electric/RCA SPY-1A radars on hulls 47-58, and the Raytheon SPY-1B radar, UYK-21 displays, and UYK-43/44 computers on subsequent hulls;
- Lockheed SPQ-91 fire control radars on earlier hulls, followed by Raytheon/RCA SPG-62 fire control radars on later hulls;
- Raytheon AN/SPS-49(v)7 air search radar

- General Dynamics MK 15 MOD 0 or MOD 2 Phalanx close-in weapon system

For antisubmarine warfare, the CG-47 class is equipped with the:

- Singer Librascope underwater fire control system MK 116 MOD 6;
- General Electric/Hughes AN/SQS-53A/B hull-mounted active search and attack sonar on hulls 47-55, replaced with the General Electric AN/SQS-53C on subsequent hulls;
- Gould AN/SQR-19 passive towed sonar array on hulls 47-55, replaced with the Gould AN/SQQ-89(v)3 on subsequent hulls;
- LAMPS MK 1 helicopter on hulls 47-48, replaced with the LAMPS MK 3 on subsequent hulls;
- MK 32 torpedo launcher; and
- Aerojet-General MK 46 or Honeywell MK 50 torpedo.

For antisurface warfare and strikes against land targets, the CG-47 class is equipped with the:

- ISC Cardion AN/SPS-55 surface search radar and
- FMC 5-inch/54 MK 45 gun.

The CG-47 class is also equipped with the:

- Raytheon AN/SLQ-32(v)3 for electronic warfare;
- Hughes Aircraft Navy Tactical Data System links 4A, 11, 14, and 16 for command, control, and communications; and
- Marconi AN/LN-66 navigation radar on hulls 47-48, replaced with the Raytheon AN/SPS-64(v)9 on subsequent hulls.

There are no full-scale development start dates in the SARs for the CG-47 class. There was no development quantity for the CG-47 class; however, the AEGIS prototype had been extensively tested at sea on board the Norton Sound (AVM-1), and the hull and propulsion systems had been proven in the DD-963 Spruance class. In spite of this background, development costs were 23 percent greater than originally estimated.

Approval for production was in January 1978, with the first production contract following in September 1978. Initial operational capability was in September 1983, six months ahead of the approved estimate. Production costs for the development estimate quantity were 6 percent less than the original March 1978 estimate. Development and cost information for the CG-47 Ticonderoga class are summarized in Table III-12.

The following acquisition initiatives have been applied to the CG-47 Ticonderoga class procurement:

- Modification of an existing platform (both hull and propulsion);
- Prototyping and extensive testing of the major subsystem—the AEGIS weapons system;
- Design and production under cost plus award fee contracts for hulls 47-53, and under fixed-price incentive contracts for hulls 54-73;
- Independent cost analysis in 1977;
- Production competition between Bath Iron Works and Ingalls Shipbuilding; and
- Dual-sourcing of subsystems.

Table III-12. CG-47 Ticonderoga Class Program Schedule and Cost Summary

	Development Estimate (12/78)	Current Estimate (12/80)	Current Estimate for Development Estimate Quantity
Development			
Start Date	1/78	1/78	N/A
End Date (IOC)	3/84	9/83	N/A
Quantity	0	0	N/A
Cost	55.5	68.2	N/A
Production			
Start Date	1/78	1/78	1/78
End Date	FY92	FY94	FY94
Quantity	16	27	16
Cost	$8,958.2	$13,939.6	$8,431.9
Construction Cost	$0.0	$14.4	$14.4
Total Program Cost	$9,013.7	$14,022.2	$8,514.5
Average Unit Cost			
Production	$559.9	$516.3	$527.0
Total Program	$563.4	$519.3	$532.2
Program Status			
Development—7 years of data			
Production—6 years of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1978 dollars.

The CG-47 Ticonderoga class was not subjected to multi-year procurement or total package procurement.

6. DD-963 Spruance Class

The primary missions of the DD-963 Spruance class are antisubmarine and antisurface warfare, as part of an aircraft carrier or surface task force, and escort and shore bombardment support for an amphibious task force. Built under a total package procurement contract by the Ingalls Shipbuilding Division of Litton Industries in a new shipyard at Pascagoula, the DD-963 has four General Electric LM2500 gas turbines on two shafts with controllable, reversible pitch propellers. The DD-963 class has hanger space for two SH-60B LAMPS helicopters. The MK 41 vertical launch system is being retrofitted to all but hulls 974, 976, 979, 983, 984, 989, and 990, for launch of the General Dynamics RIM-66 Standard Missile 2–Medium Range for antiair warfare, the McDonnell Douglas RGM-84 Harpoon cruise missile for antisurface warfare, the General Dynamics BGM-109 Tomahawk cruise missile for strikes against ship and land targets, and the Honeywell RUR-5A antisubmarine rocket for antisubmarine warfare.

For antisubmarine warfare, the DD-963 class is equipped with the:

- General Electric/Hughes AN/SQS-53A/B hull-mounted active and passive sonar, which is being upgraded to the General Electric AN/SQS-53C;
- General Electric AN/SQR-19 TACTAS passive towed array sonar, which is being upgraded to the Gould AN/SQQ-89(v)6;
- Singer-Librascope MK 116 antisubmarine warfare fire control system;
- MK 32 torpedo launcher; and
- Aerojet-General MK 46 or Honeywell MK 50 torpedo.

For antiair warfare, the DD-963 class is equipped with the:

- Lockheed AN/SPS-40B/C/D air search radar on hulls 963-996, and Raytheon AN/SPS 9V on hull 997;
- Raytheon Sea-Sparrow launcher MK 29 for RIM-7 missiles; and
- General Dynamics MK 15 Phalanx close-in weapon system.

For antisurface warfare and strikes against land targets, the DD-963 class is equipped with the:

- FMC 5-inch/54 MK 45 gun;
- ISC Cardion AN/SPS-55 surface search radar;
- Lockheed AN/SPG-60 gun tracking and illuminator radar;
- Lockheed AN/SPQ-9A or Raytheon MK 91 surface search weapons control radar;

- Lockheed Electronics Company MK 86 gun fire control system; and
- McDonnell Douglas RGM-84 Harpoon antiship missile;

The DD-963 class is also equipped with the:

- Raytheon AN/SLQ-32(v)2 for electronic warfare;
- Hughes Aircraft Navy Tactical Data System links 11 and 14 for command, control, and communications; and
- Raytheon AN/SPS-64(v) radar for navigation.

The DD-963 Spruance class was procured to replace the destroyers procured during World War II, which were facing block obsolescence. The DD-963 class differs from its predecessors in a number of ways. It was the first U.S. combatant to have gas turbine propulsion and controllable, reversible pitch propellers. It was the first total package procurement for a ship program. The same contractor, the Ingalls Shipbuilding Division of Litton Industries, was responsible for both design and construction. The contractor was given great leeway in designing the ship to meet broad performance and physical requirements, with minimal detailed design guidance from the Navy. The ships were the first to be built in a new, and for that time, revolutionary shipyard using modular construction techniques. Many of the design and production personnel had never previously worked in a shipbuilding program; many of the design personnel were from the aerospace industry, and they brought to the program an emphasis on systems analysis techniques.

The DD-963 class has been an operational success, but was a financial disaster. The same contractor had a total package procurement contract for the LHA during the same time period, and those two programs almost bankrupted Litton Industries.

Engineering development commenced in June 1970. The gas turbine propulsion system had previously been prototyped and tested extensively at sea in a cargo ship. The controllable pitch propeller had been prototyped and tested at sea on the Patterson (FF-1061) and Barbey (FF-1088). The combat information system was prototyped at Litton Industries facilities in Culver City. Production started in June 1972, seven months ahead of schedule. The initial operational capability was five years later, two years behind schedule.

A small part (less than 2 percent) of the total package procurement cost was paid for out of development appropriations, and that amount was 6.4 percent greater than what had originally been estimated. The total production costs of $2,649.9 million in fiscal year 1970 constant dollars shown in the latest available SAR (December 1978), do not include the costs for the settlement of the cost overrun negotiations between the Navy and Litton

Industries. As a result of that settlement, production costs were increased by approximately $354.41 million in 1970 constant dollars, to obtain a revised estimate for total production costs for the 31 ships of the DD-963 class of $3,004.3 million in 1970 constant dollars, as shown in Table III-13.

Table III-13. DD-963 Production Cost Calculation

	1970 Dollars
Production costs in 1278 SAR	2,649.9
Settlement:	
+ Economic changes	243.5
+ Contract cost overrun	184.3
+ Other cost overrun	.8
+ PL 85-804 contract settlement	64.5
- Costs already included in 12/78 SAR	-138.7
Production costs for 31 ships	3,004.3
- Contract cost of 31st ship	-82.1
Production costs for the 30 ships of the development estimate	2,922.2

The total production costs for the first 30 ships of the original quantity was obtained simply by subtracting the incremental contract cost for the 31st ship of $82.1 million 1970 constant dollars. Using that total production cost of $2,922.2 in 1970 constant dollars for the first 30 ships, production costs increased by 23 percent over what was originally estimated. Development and cost information for the DD-963 Spruance class are summarized in Table III-14.

After the contract for the first thirty ships, four additional Spruance class ships were ordered for the Iranian navy, with an enhanced antiair warfare capability. Because of the overthrow of the Shah, Iran never took delivery of these ships, and they became the DD-993 Kidd class (often referred to as the Ayatollah class). A 31st Spruance class ship, DD-996, was also completed.

The following acquisition initiatives have been applied to the DD-963 Spruance class procurement:

- A competitive advanced development was held;
- The propulsion system and the combat information system were prototyped, and the propulsion system was extensively tested at sea; and
- The first 30 ships were procured under a multi-year total package procurement with a fixed price incentive contract covering both development and production.

Table III-14. DD-963 Spruance Class Program Schedule and Cost Summary

	Development Estimate (12/69)	Current Estimate (12/78)	Current Estimate for Development Estimate Quantity
Development			
Start Date	06/70	06/70	N/A
End Date (IOC)	06/75	06/77	N/A
Quantity	0	0	N/A
Cost	$36.0	$38.3	N/A
Production			
Start Date	1/73	6/72	6/72
End Date	1/79	2/83	2/83
Quantity	30	31	30
Cost	$2,372.1	$3,004.3	$2,922.2
Total Program Cost	$2,408.1	$3,042.6	$2,960.5
Average Unit Cost			
Production	$79.1	$96.9	$97.4
Total Program	$80.3	$98.1	$98.7
Program Status			
Development—Completed			
Production—Completed			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1970 dollars.

7. DDG-51 Arleigh Burke Class

The primary missions of the DDG-51 class are antiair, antisubmarine, and antisurface warfare, as part of an aircraft carrier or surface task force. It was designed by the Navy, and the detailed design and construction are being done by the Bath Iron Works and the Ingalls Shipbuilding Division of Litton Industries. It is the Navy's second class of AEGIS-equipped ships, and was originally conceived to be a less costly supplement to the CG-47 Ticonderoga class. The DDG-51 class has four General Electric LM2500 gas turbines on two shafts with controllable, reversible pitch propellers, similar to the propulsion systems of the DD-963 and CG-47 classes. The DDG-51 class does not have a helicopter hanger, but will have the capability of landing and refueling SH-60B LAMPS helicopters. The DDG-51 class is equipped with the MK 41 vertical launch system, for launch of the General Dynamics RIM-66 Standard Missile 2–Medium Range, the McDonnell Douglas RGM-84 Harpoon cruise missile, the General Dynamics BGM-109 Tomahawk cruise missile, and the Honeywell RUR-5A antisubmarine rocket MK 16 torpedo/missile.

For antiair warfare, the DDG-51 class is equipped with the:

- General Electric RCA Government Systems Division AEGIS air defense system with the AN/SPY-1D phased array radar;
- Raytheon/RCA AN/SPG-62 missile fire control radars; and
- General Dynamics MK 15 Phalanx close-in weapon system.

For antisubmarine warfare, the DDG-51 class is equipped with the:

- Gould AN/SQQ-89 sonar system, consisting of the AN/SQS-53C hull-mounted active and passive sonar, the AN/SQR-19 TACTAS towed passive sonar array, and the AN/SQR-4 LAMPS-III terminal; and
- Aerojet-General MK 46 or Honeywell MK 50 torpedo.

For antisurface warfare, the DDG-51 class is equipped with the:

- FMC 5-inch/54 MK 45 MOD 1 gun;
- Norden AN/SPS-67 surface search radar; and
- MK 160 gunfire control system;

The DDG-51 class is also equipped with the:

- Raytheon AN/SLQ-32(v)2 in hulls 51-58, and AN/SLQ-32(v)3 in subsequent hulls, for electronic warfare;
- Hughes Aircraft Navy Tactical Data System MOD 5 with links 4A, 11, 14, and 16, for command, control, and communications; and
- Raytheon AN/SPS-64(v)9 radar for navigation.

The DDG-51 class differs from its immediate predecessors, the DD-963 and CG-47 classes, in several ways. It has a wider beam, for more kindly sea-keeping in heavy seas. The shape of the hull, superstructure, and top-hamper is designed to minimize radar returns. Steel is used in place of aluminum in order to reduce the fire hazard.

Detailed design and construction of the DDG-51 class was authorized in December 1983. Production started October 1986, two months behind schedule. As of the December 1989 SAR, initial operational capability was estimated for February 1992, 16 months behind schedule.

A consistent original estimate of development costs for the DDG-51 class cannot be obtained from the SARs because of the re-baselining of the program in 1985 and 1987. Prior to 1985, constant costs were expressed in 1981 base year dollars. For 1985 and 1986, constant costs were expressed in 1984 base year dollars. Since 1986, constant costs have been expressed in 1987 base year dollars. For each of the SARs from December 1982

through December 1986, original and current estimates of development costs in 1987 base-year dollars were calculated using the appropriate base-year 1991 RDT&E Navy deflators. The current estimate as of December 1989 for development costs is 39.7 percent greater than the development estimate. Production costs for the originally estimated quantity of 9 are expected to be approximately 13.5 percent less than originally expected. Development and production cost data for the DDG-51 Arleigh Burke class are summarized in Table III-15.

The following acquisition initiatives have been applied to the DDG-51 Arleigh Burke class procurement:

- Use of modified subsystems from previous ship classes with extensive operational experience;
- Design-to-cost;
- Dual-source production competition with fixed-price incentive contracts;
- Competitive multi-year procurement planned for fiscal year periods 1990-91 and 1992-94, with fixed-price incentive contracts;
- Procurement streamlining with each buy.

Table III-15. DDG-51 Arleigh Burke Class Program Schedule and Cost Summary

	Development Estimate (12/82)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	5/82	12/83	N/A
End Date (IOC)	3/90	10/90	N/A
Quantity	0	0	N/A
Cost	$892.2	$1,240.5	N/A
Production			
Start Date	8/86	10/86	10/86
End Date	FY93	FY01	FY01
Quantity	9	38	9
Cost	$6,794.1	$22,663.6	$6,389.7
Military Construction	$25.6	$25.4	$25.4
Total Program Cost	$7,711.9	$23,929.5	$7,655.6
Average Unit Cost			
Production	$754.9	$596.4	$710.0
Total Program	$856.9	$629.7	$850.6
Program Status			
Development—8 years of data			
Production—8 years of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1987 dollars.

8. FFG-7 Oliver Hazard Perry Class

The FFG-7 Oliver Hazard Perry class was developed as a "low-end" ship with limited capabilities with the mission to protect underway replenishment groups, amphibious forces, and military shipping from submarine, air, and surface threats. It was designed by Gibbs and Cox, and was produced at the Bath Iron Works, Todd Seattle, and Todd San Pedro shipyards for the United States and Australia. It has also been produced in Australia, Spain, and Taiwan for the navies of those nations. It has two General Electric LM-2500 gas turbines driving a single shaft with a controllable, reversible pitch propeller—basically one-half of the propulsion system that had received extensive operational use in the DD-963 Spruance class. It is equipped with one FMC MK 13 MOD 4 missile launch system for firing the General Dynamics RIM-66 Standard Missile 1–Medium Range for antiair warfare, and the McDonnell Douglas RGM-84 Harpoon for antisurface warfare. It has a hanger for the LAMPS helicopter and a helicopter landing system.

For antiair warfare, the FFG-7 class is equipped with the:

- Raytheon AN/SPS-49(v)4/5 air search radar;
- General Dynamics Phalanx close-in weapon system; and
- Sperry MK 92 MOD 2 (MOD 6 on hull 61) fire control system.

For antisubmarine warfare, the FFG-7 class is equipped with the:

- Gould AN/SQQ-89(v)2 sonar system, consisting of the AN/SQS-53B hull-mounted active and passive sonar, and the AN/SQR-19 TACTAS towed passive sonar array, originally fitted on hulls 8 and 36-61, and being retrofitted on all others, which were originally equipped with the Raytheon AN/SQS-56 hull-mounted active and passive sonar;
- MK 309 torpedo fire control system;
- MK 32 torpedo launcher; and
- Aerojet-General MK 46 or Honeywell MK 50 torpedo.

For antisurface warfare, the FFG-7 class is equipped with the:

- ISC Cardion AN/SPS-55 surface search radar and
- Oto-Melera 3-inch (76mm)/62 MK 75 gun.

The FFG-7 class is also equipped with the:

- Raytheon AN/SLQ-32(v)2, for electronic warfare and
- Hughes Aircraft navy tactical data system with links 11 and 14, for command, control, and communications.

Engineering development started in October 1972. Before that, most of the major systems had already been developed and were in use on other ship classes. The controllable, reversible pitch propeller had been prototyped and tested on the Patterson (FF-1061) and Barbey (FF-1088). The AN/SQS-56 sonar had been prototyped and tested on the DD-840. In spite of this, development costs were 40 percent greater than originally expected. Production was authorized in December 1975, nine months behind schedule. Initial operational capability was attained in March 1979, ten months behind schedule. The production span was increased from an originally expected 90 months to 165 months, with an increase of only one in the quantity produced. Production costs were 59 percent greater than originally expected. Development and cost information for the FFG-7 Oliver Hazard Perry class are summarized in Table III-16.

Table III-16. FFG-7 Oliver Hazard Perry Class Program Schedule and Cost Summary

	Development Estimate (12/75)	Current Estimate (12/86)	Current Estimate for Development Estimate Quantity
Development			
Start Date	10/72	10/72	N/A
End Date (IOC)	5/78	3/79	N/A
Quantity	0	0	N/A
Cost	$14.1	$19.7	N/A
Production			
Start Date	3/75	12/75	12/75
End Date	FY82	FY89	FY89
Quantity	50	51	50
Cost	$2,606.3	$4,333.9	$4,138.7
Total Program Cost	$2,620.4	$4,353.6	$4,158.4
Average Unit Cost			
Production	$52.10	$85.0	$82.8
Total Program	$52.40	$85.4	$83.2
Program Status			
Development—Completed			
Production—Completed			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1973 dollars.

The following acquisition initiatives have been applied to the FFG-7 Oliver Hazard Perry class procurement:

- Prototyping of the propulsion and sonar systems;
- Extensive use of modified subsystems from other ship classes;
- Design-to-cost in 1971-1981;

- Independent cost analyses in 1976 and 1976;
- Independent test;
- Competitive ship construction in three different shipyards;
- Cost plus fixed fee, and cost plus incentive fee contracts for full-scale development;
- Fixed-price incentive contracts for production.

Notably for a program of this size during that time period, neither total package procurement nor multi-year procurement were used.

9. LHA-1 Tarawa Class

The primary mission of the LHA-1 class is to transport Marine helicopters, and combat personnel with their equipment, and provide a platform for helicopter operations during amphibious assaults. The class has a well dock, which can be flooded, for use in off-loading personnel and equipment into landing craft. The class has no defense capabilities against submarine threats, and minimal capabilities against surface and air threats. The LHA-1 class has two Combustion Engineering boilers and two Westinghouse geared turbines driving twin propulsion shafts. The class was built by the Ingalls Shipbuilding Division of Litton Industries, in their Pascagoula shipyard, while the DD-963 Spruance class destroyers were still being built there. Those two programs almost bankrupted Litton Industries.

For defense against air and surface threats, the LHA-1 class is equipped with the:

- Lockheed AN/SPS-40B/C/D air search radar;
- Hughes AN/SPS-52C air search radar;
- Raytheon AN/SPS-67 surface search radar;
- Lockheed AN/SPG-60 fire control system;
- Lockheed AN/SPQ-91 fire control system;
- FMC 5-inch/54 MOD 1 gun;
- General Dynamics MK 15 Phalanx close-in weapon system; and
- McDonnell Douglas MK 242 25mm automatic cannon.

The LHA-1 class is also equipped with the:

- Raytheon AN/SLQ-32v(3) for electronic warfare;
- Motorola AN/SSR-1 satellite communications system; and

- Raytheon AN/SPS-64(v)9 navigation radar.

The LHA-1 class was a follow-on to the LPH-2 Iwo Jima class, which was the first class of ships built from the keel up to support Marine helicopter operations during amphibious assaults. The LHA-1 class is larger, faster, and carries more helicopters and marines than its predecessors. The addition of the well dock provides increased flexibility in the load-out of the amphibious force.

Development of the LHA-1 class was authorized in April 1969 with a fixed-price incentive contract for a total package procurement. Costs allocated to the development appropriation were very slightly (less than 0.5 percent) less than originally expected.

Production started in January 1971, three months behind the originally scheduled date. In June 1976, Ingalls Shipbuilding stopped work because their expenses were greatly exceeding the progress payments under the contract, creating serious cash flow problems for Litton Industries and the potential for a huge cost over-run, which they would have to absorb. Following a series of legal actions by both the Navy and Litton Industries, a preliminary injunction was issued that forced Litton Industries to continue working and forced the Navy to pay 91 percent of the actual costs incurred by Litton while the injunction remained in effect. By May 1977, Navy payments under the injunction exceeded the contract value. The injunction was extended, and in June 1978, an agreement was reached between the Navy and Litton Industries for both the DD-963 Spruance class and LHA-1 Tarawa class programs, under which the target prices for both programs were increased by a total of approximately $447 million, leaving Litton Industries with a loss of over $200 million on the two programs. Production costs for the quantity estimated at the start of development were 58 percent greater than the cost estimate made at the start of development. The production costs for the quantity estimated at the start of development were calculated from the current estimate of production costs using an assumed 90 percent cost improvement curve, because no annual quantities were shown in the SARs that could be used for directly estimating the first unit cost and slope of the cost improvement curve.

Initial operational capability was attained in May 1977, 39 months behind schedule. The production quantity was decreased from nine to five, and production ended five years later than originally expected. Development and cost information for the LHA-1 Tarawa class are summarized in Table III-17.

Only limited information was available to show the acquisition initiatives that were applied to the LHA-1 Tarawa class procurement. The LHA-1 Tarawa class was the only

program of the fifteen ship programs in this study for which the Navy was not able to provide this information. The SARs showed that the following initiatives were used:

- Total package procurement; and
- Fixed-price incentive contract to cover both development and production.

Table III-17. LHA-1 Tarawa Class Program Schedule and Cost Summary

	Development Estimate (12/69)	Current Estimate (12/78)	Current Estimate for Development Estimate Quantity
Development			
Start Date	12/68	4/69	N/A
End Date (IOC)	2/74	5/77	N/A
Quantity	0	0	N/A
Cost	$22.3	$22.2	N/A
Production			
Start Date	10/70	1/71	1/71
End Date	FY76	FY81	FY81
Quantity	9	5	9
Cost	$1,269.0	$1,215.5	$2,001.0
Total Program Cost	$1,291.3	$1,237.7	$2,023.2
Average Unit Cost			
Production	$141.0	$243.1	$222.3
Total Program	$143.5	$247.5	$224.8
Program Status			
Development—Completed			
Production—Completed			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1969 dollars.

10. LHD-1 Wasp Class

The primary mission of the LHD-1 class is to transport Marine helicopters and combat personnel with their equipment, and provide a platform for helicopter operations during amphibious assaults. A hospital is provided for the care of combat casualties. The class is a modification of the LHA-1 Tarawa class. Similar to the LHA-1 class, this class has a well dock that can be flooded for off-loading landing craft. The LHD-1 class is designed to carry 6-8 AV-8B Harriers or up to 20 in a secondary role. The LHD-1 class has two Combustion Engineering boilers and two Westinghouse geared turbines driving twin propulsion shafts. The class was built by the Ingalls Shipbuilding Division of Litton Industries, in their Pascagoula shipyard.

To support Marine amphibious operations, the LHD-1 class is equipped with the:

- Integrated Tactical Amphibious Warfare Data System (ITAWDS); and
- Marine Tactical Amphibious Command and Control System (MTACCS) with links 4A and 11, with links 14 and 16 to be added later.

For defense against air and surface threats, the LHD-1 class is equipped with the:

- Hughes AN/SPS-52C air search radar on LHD-1, and ITT AN/SPS-48E air search radar on subsequent hulls;
- Raytheon AN/SPS-49(v)9 air search radar;
- Hughes MK 23 target acquisition system radar;
- Norden AN/SPS-67 surface search radar;
- Raytheon MK 29 guided missile launch system for the Raytheon RGM-7 Sea Sparrow for antiair warfare; and
- General Dynamics MK 15 Phalanx close-in weapon system.

The LHD-1 class is also equipped with the:

- Raytheon AN/SLQ-32(v)3 for electronic warfare;
- Motorola AN/SSR-1 satellite communications system; and
- Raytheon AN/SPS-64(v)9 navigation radar.

The LHD-1 class provided the additional lift required by the Marines Corps' increasing emphasis on helicopter assault, which was being constrained by the shortfall caused by the cancellation of the last four of the LHA-1 Tarawa class.

Development of the LHD-1 class was authorized in July 1982. Development costs were 9.3 percent greater than originally estimated. Production started in February 1984, two months behind schedule. Initial operational capability was attained in October 1990, six months behind schedule. Production costs for the originally specified quantity were 6 percent less than originally estimated. Development and cost information for the LHD-1 Wasp class are summarized in Table III-18.

The following acquisition initiatives have been applied to the LHD-1 Wasp class procurement:

- Modification of an existing ship type, the LHA-1 Tarawa class;
- Extensive use of already developed systems from other ships;
- Design-to-cost from June 1982 through February 1984;
- Independent cost analysis in August 1982 and August 1987;

- Procurement streamlining with each buy;
- Non-competitive cost plus award fee contracts for full-scale development; and
- Sole-source, fixed-price incentive production contract for LHD-1, followed by competitive multi-year, fixed-price incentive procurement contract for hulls 2-4 in 1986.

Table III-18. LHD-1 Wasp Class Program Schedule and Cost Summary

	Development Estimate (6/83)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	7/82	7/82	N/A
End Date (IOC)	4/90	10/90	N/A
Quantity	0	0	N/A
Cost	$39.9	$43.6	N/A
Production			
Start Date	12/83	6/83	6/83
End Date	FY93	FY98	FY98
Quantity	3	6	3
Cost	$2,891.9	$4,685.5	$2,724.0
Total Program	$2,931.8	$4,729.1	$2,767.6
Average Unit Cost			
Production	$964.0	$780.9	$908.0
Total Program	$977.3	$788.2	$922.5
Program Status			
Development—Completed			
Production—5 years of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1982 dollars.

11. LSD-41 Whidbey Island Class

The mission of the LSD-41 Whidbey Island Class is to transport and offload Marines and their equipment into landing craft during an amphibious assault. The LSD-41 class has no capabilities for defense against submarines, and very limited capabilities for defense against air or surface threats. It is a modification of the LSD-36 Anchorage class, with four commercial Colt-Pielstick 16PC25-v400 diesels driving two shafts with controllable pitch propellers. The LSD-41 class was designed by Lockheed Shipbuilding and Construction, and is being built by Lockheed Shipbuilding and Construction, and Avondale Shipyards.

For defense against air and surface threats, the LSD-41 class is equipped with the:

- Raytheon AN/SPS-49 air search radar;

- Norden AN/SPS-67 surface search radar; and
- General Dynamics MK 15 Phalanx close-in weapon system on hulls 41-46, replaced by the McDonnell Douglas MK 88 25mm Bushmaster gun on hulls 47 and 48.

The LSD-41 class is also equipped with the:

- Raytheon AN/SLQ-32(v)1 for electronic warfare;
- Motorola AN/SSR-1 satellite communications system; and
- Raytheon AN/SPS-64(v)9 navigation radar.

The LSD-41 class replaces previous classes that were becoming worn out. The commercial diesels were selected to reduce engine room maintenance and manning requirements.

Development of the LSD-41 class was authorized in November 1978. Development costs were 9.2 percent greater than had been originally estimated. Production started in January 1981 with a contract to Lockheed for the lead ship. Contracts for the first two follow-up ships were awarded to Lockheed in March 1982 and January 1983. In November 1983, Avondale won a competitive award for hull 44, with options for hulls 45-48. Initial operational capability was attained in February 1986, three months behind schedule. Production costs for the originally specified quantity were 8 percent less than originally estimated. Development and cost information for the LSD-41 Whidbey Island class are summarized in Table III-19.

The following acquisition initiatives have been applied to the LSD-41 Whidbey Island class procurement:

- Use of a commercially developed diesel propulsion system that has been widely used in merchant shipping;
- Extensive use of subsystems already in use on the LSD-36 Anchorage class;
- Full-scale development competition;
- Design-to-cost, from June 1982 to February 1984;
- Independent cost evaluation;
- System production competition between Lockheed and Avondale;
- Cost plus award fee contract for lead ship design and construction, later converted to cost plus fixed fee with ceiling contract;
- Cost plus award fee contract for the first follow-up ship, later converted to fixed-price incentive contract;

- Fixed-price incentive contract for the second follow-up ship; and
- Competitively awarded firm fixed-price contract for hull 44 with options for hulls 45-48.

Table III-19. LSD-41 Whidbey Island Class Program Schedule and Cost Summary

	Development Estimate (6/83)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	11/78	11/78	N/A
End Date (IOC)	11/85	2/86	N/A
Quantity	0	0	N/A
Cost	$46.9	$51.2	N/A
Production			
Start Date	1/81	1/81	1/81
End Date	FY92	FY92	FY92
Quantity	12	8	12
Cost	$3,177.0	$2,00.5	$2,913.8
Total Program Cost	$3,223.9	$2,051.7	$2,965.0
Average Unit Cost			
Production	$264.8	$250.1	$242.8
Total Program	$268.7	$256.5	$247.1
Program Status			
Development—Completed			
Production—10 years of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1970 dollars.

12. LSD-41 CV Harpers Ferry Class

The LSD-41 CV (cargo version) Harpers Ferry class is a modification of the LSD-41 Whidbey Island class, with a smaller well dock replaced by greater cargo area. The mission and the equipment are the same as for the LSD-41 Whidbey Island class. The ships are being built by Avondale Shipyards.

Development of the LSD-41 cargo version was authorized in December 1987. Actual development costs were 17 percent below the original estimate. Production started in November 1989, four months behind schedule. Initial operational capability currently estimated for October 1994, one month behind schedule. Production costs for the originally specified quantity are currently estimated to be 22 percent less than originally estimated. Development and cost information for the LSD-41 cargo version Harpers Ferry class are summarized in Table III-20.

The following acquisition initiatives have been applied to the LSD-41 cargo version Harpers Ferry class procurement:

- Modification of an already in-use design, with all systems demonstrated on the LSD-41 Whidbey Island class;
- Design-to-cost in 1986;
- Independent cost evaluation in 1987; and
- Production competition between Avondale and Lockheed for multi-year, fixed-price incentive contract.

Table III-20. LSD-41 CV Harpers Ferry Class Program Schedule and Cost Summary

	Development Estimate (12/37)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	12/87	12/87	N/A
End Date (IOC)	9/94	10/94	N/A
Quantity	0	0	N/A
Cost	$15.4	$12.9	N/A
Production			
Start Date	7/89	11/89	11/89
End Date	FY99	FY99	FY99
Quantity	5	6	5
Cost	$1,335.3	$1,340.7	$1,040.2
Total Program Cost	$1,350.7	$1,353.6	$1,053.1
Average Unit Cost			
Production	$267.1	$223.5	$208.0
Total Program	$270.1	$225.6	$210.6
Program Status			
Development—2 years of data			
Production—1 year of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1988 dollars.

13. SSN-21 Seawolf Class

The primary mission of the SSN-21 Seawolf class is to conduct operations against enemy submarines and surface ships with torpedoes and mines, and against surface ships and land targets with cruise missiles. The SSN-21 class will be equipped to launch the Gould MK 48 ADCAP torpedo, the McDonnell Douglas RGM-84 cruise missile, the General Dynamics BGM-109 Tomahawk cruise missile, and various mines through torpedo tubes. The class will be capable of operations under the polar ice pack. The SSN-

21 class is powered with one General Electric S6W nuclear reactor, which generates steam for turbines that drive a single shaft with a pumpjet propulsor. Design contracts were with Newport News Shipbuilding and Dry Dock and the Electric Boat division of General Dynamics. Newport News is lead on the detailed design contract. Electric Boat is producing the first hull.

The SSN-21 class will be equipped with the:

- IBM AN/BQQ-5D hull-mounted passive/active search and attack sonar;
- Martin Marietta TB-16 towed sonar surveillance array;
- Martin Marietta TB-23 passive towed sonar tactical array;
- GTE Electronic Defense Systems Sector AN/WLQ-4(v)1 electronic signal intercept system;
- General Electric AN/BSY-2(v) submarine combat system with AN/UYK-44 computers; and
- Raytheon MK 2 torpedo fire control system.

The SSN-21 class will be much quieter and have greater signal detection and processing capabilities for detecting other submarines or surface ships than the predecessor SSN-688 Los Angeles class. The reduction in noise will allow the SSN-21 class to detect other submarines and surface ships while operating at higher underwater speeds and avoid being detected itself. Its torpedo tubes are wider than the previous standard 21", allowing a greater variety of weapons to be launched through the torpedo tubes.

Full-scale development of the SSN-21 class started in June 1985, one month behind schedule. As of the December 1989 SAR, total development costs were expected to be $2,332.1 million in 1985 constant dollars, 35.2 percent greater than originally estimated. These development costs do not include those costs of developing the nuclear power system that are covered by Department of Energy appropriations; those costs are not reported in the SARs.

Start of production was authorized in June 1988, 21 months ahead of schedule. As of the December 1989 SAR, initial operational capability will be in May 1995, six months behind schedule. Production costs for the originally specified quantity of 1 (the first of the SSN-21 class) are currently estimated to be $2,651.4 in 1985 constant dollars, which is 86 percent greater than originally estimated, based on very limited data. These production costs include the costs for producing the AN/BSY-2 submarine combat system and the other combat systems with which the class is equipped. These production costs do not

include those costs for the nuclear power system that were funded by Department of Energy appropriations; those costs are not reported in the SARs. Development and cost information for the SSN-21 Seawolf class are summarized in Table III-21.

The following acquisition initiatives have been applied to the SSN-21 Seawolf class procurement:

- Prototyping of the nuclear power plant and the hull materials;
- Competition for full-scale development of the nuclear power plant in January 1991;
- Independent cost evaluations in May 1985, May 1988, September 1989, and April 1990;
- Procurement streamlining in August 1985;
- Cost plus fixed-fee development contract in April 1987;
- Fixed-price incentive production contract in January 1989; and
- Potential dual-sourcing or competitive bids for future hulls.

Table III-21. SSN-21 Seawolf Class Program Schedule and Cost Summary

	Development Estimate (12/84)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	5/85	6/85	N/A
End Date (IOC)	11/94	5/95	N/A
Quantity	0	0	N/A
Cost	$1,724.6	$2,332.1	N/A
Production			
Start Date	3/90	6/88	6/88
End Date	FY97	FY99	FY99
Quantity	1	9	1
Cost	$1,425.0	$10,963.0	$2,651.4
Construction Cost	$83.6	$62.3	$62.3
Total Program Cost	$3,233.2	$13,357.4	$5,045.8
Average Unit Cost			
Production	$1,425.0	$1,218.1	$2,651.4
Total Program	$3,233.2	$1,484.2	$5,045.8
Program Status			
Development—6 years of data			
Production—3 years of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1985 dollars.

14. SSN-688 Los Angeles Class

The primary mission of the SSN-688 class is to conduct operations against enemy submarines and surface ships with torpedoes and mines, against surface ships and land targets with cruise missiles, and to provide submarine escort for aircraft carrier task forces. The SSN-688 class is equipped with four 21-inch diameter torpedo tubes amidships, to launch the MK 48 and the Gould MK 48 advanced capability torpedoes, the McDonnell Douglas RGM-84 cruise missile, the General Dynamics BGM-109 Tomahawk cruise missile, the MK 57 mine, and the MK 60 Captor mine. Beginning with hull 719, a vertical launch capability is provided for the BGM-109 Tomahawk cruise missile from 12 launch tubes outside the pressure hull. Beginning with hull 751, acoustic tile cladding is provided, along with an under-ice capability with a strengthened sail and retractable planes mounted forward instead of fixed on the sail. The SSN-688 class is powered with one General Electric S6G nuclear reactor, which generates steam for two turbines driving a single propeller shaft. The SSN-688 class is being built by Newport News Shipbuilding and Dry Dock and the Electric Boat division of General Dynamics.

The SSN-688 class is equipped with the:

- IBM AN/BQQ-5(v)1 hull mounted passive/active search and attack sonar, being updated to the IBM AN/BQQ-5D;
- AN/BQR-23/25 passive towed sonar array, being replaced with the Martin Marietta TB-23 thin line passive towed sonar array;
- KETEMA AN/BQS-15 AMETEK active ice detection sonar, replaced by the Hazeltine/IBM AN/BQS-14A mine and ice detection and avoidance system sonar on hulls 751 and subsequent;
- Raytheon SADS-TG active detection system (being retrofitted);
- Raytheon CCS MK 1 combat data system with AN/UYK-7 computers on hulls 688-750, and the IBM AN/BSY-1 submarine combat system with AN/UYK-43 and AN/UYK-44 computers on hulls 751-773;
- Singer Librascope MK 113 MOD 10 torpedo fire control system in hulls 688-699, being replaced with the MK 117 torpedo fire control system in hulls 688-699 and installed as new equipment on hulls 700-750; and
- Sperry AN/BPS-15 surface search/navigation radar.

The SSN-688 class submarines are larger, faster, and quieter than their predecessor SSN-37 Sturgeon class. The larger size is mostly accounted for by a larger propulsion

plant. The SSN-688 class also has more capable sonar and fire control systems than its predecessor class. Because of its size, military construction expenditures were required for dredging of berthing areas.

Development of the SSN-688 class was authorized in November 1968. Development costs through IOC were approximately $4.8 million constant 1971 dollars, 7.7 percent less than originally estimated. As of the December 1989 SAR, total development costs are estimated to be $24.5 million constant 1971 dollars, 4.7 times the amount originally estimated. The difference in development costs between IOC and the present time is due to the additional capabilities incorporated in the class. These development costs do not include the costs of developing the nuclear power system that are covered by Department of Energy appropriations; those costs are not reported in the SARs.

Start of production was authorized in January 1971. Initial operational capability was attained in November 1976, 34 months behind schedule. Production costs for the originally specified quantity were $5,089.9 million constant 1971 dollars, 1 percent less than the original estimate. These production costs include the costs for producing the AN/BSY-1 submarine combat system and the other combat systems with which the class is equipped. These production costs do not include the costs for the nuclear power system funded by Department of Energy appropriations; those costs are not reported in the SARs. Development and cost information for the SSN-688 Los Angeles class are summarized in Table III-22.

The following acquisition initiatives have been applied to the SSN-688 Los Angeles class procurement:

- Modification of the General Electric D2G nuclear powerplant previously used on the CGN-25 Bainbridge and CGN-35 Truxton;
- Independent cost evaluation;
- Dual-sourcing of production, at Electric Boat and Newport News; and
- Fixed-price incentive production contracts.

It is unusual that the program (during that time period with as large a quantity) was not subject to total package procurement or multi-year procurement.

Table III-22. SSN-688 Los Angeles Class Program Schedule and Cost Summary

	Development Estimate (12/69)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	11/68	11/68	N/A
End Date (IOC)	9/73	11/76	N/A
Quantity	0	0	N/A
Cost	$5.2	$4.8	N/A
Production			
Start Date	1/71	1/71	1/71
End Date	FY87	FY97	FY97
Quantity	10	62	10
Cost	$5,126.8	$11,413.3	$5,089.9
Construction Cost	$16.7	$20.4	$20.4
Total Program Cost	$5,148.7	$11,438.5	$5,115.1
Average Unit Cost			
Production	$512.7	$184.1	$509.0
Total Program	$514.9	$184.5	$511.5
Program Status			
Development—Completed			
Production—22 years of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1971 dollars.

15. TAO-187 Henry J. Kaiser Class

The mission of the TAO-187 Henry J. Kaiser class of replenishment oilers is to:

- Deliver bulk petroleum products from shore depots to surface combatants and AOE, AOR, AO, and T-AO class support ships, both underway and in port and
- Receive and deliver fleet freight, mail, and personnel to and from combatant and support force ships underway and in port.

It is operated by civil service or contract crews, and is equipped with no defensive weapons. It has two propeller shafts, powered by two commercial Colt-Pielstick 10-PC4.2V diesels on hulls 187-189, and two commercial Fairbanks Morse diesels on the remaining hulls. The commercial diesels were selected for fuel economy and to reduce engine room maintenance and manning requirements. The underway replenishment gear had been developed and proven on previous replenishment oiler classes. The detailed design of the TAO-187 class was by Avondale Shipyards, and the class is being built by Avondale Shipyards, Pennsylvania Shipbuilding ("Penn"), and Tampa Shipyard. Hulls

191 and 192 were started by Penn, but not completed before that company went into bankruptcy. Tampa Shipyard was awarded the contract for completion of hulls 191 and 192.

Development of the TAO-187 class was started in December 1981. Actual development costs were $15.3 million 1984 constant dollars, 3.2 percent less than the original estimate. Avondale had previously designed and built the similar but smaller AO-177 Cimarron class replenishment oiler, which had steam propulsion. In spite of that experience, there were design difficulties with the TAO-187 class, with excessive vibration at high speeds and other problems.

Production was started on schedule in November 1982 at Avondale, with a contract for hull 187 with options for hulls 188-190 and a subsequent option for hull 193. Penn received a contract in May 1985 for hulls 190 and 191, with options for hulls 194 and 196, all to be built in a new shipyard opened by Penn. The options on hulls 194 and 196 were transferred to Avondale in June 1988 when it became obvious that Penn was having difficulties fulfilling the contract for hulls 191 and 192. The contract with Penn was terminated for default in August 1989 when Penn went bankrupt. Avondale subsequently received options for hulls 195 and hulls 197-204. In spite of the problems, production costs for the originally specified quantity were $2,381.1 million constant 1984 dollars, 8 percent less than the original estimate. Initial operational capability was in February 1987, 3 months behind schedule. Development and cost information for the TAO-187 Henry J. Kaiser class are summarized in Table III-23.

The following acquisition initiatives have been applied to the TAO-187 Henry J. Kaiser class procurement:

- Use of commercially available propulsion system;
- Prototyping of underway replenishment gear;
- Competition at the subsystem level during full-scale development;
- Independent cost evaluation in April 1979;
- Independent test of the underway replenishment gear;
- Streamlining of the follow-on procurements;
- Dual-sourcing of the production between Avondale and Penn/Tampa;
- Dual-sourcing of the production of the underway replenishment gear;
- Fixed-price incentive and firm fixed-price contracts for development;

- Fixed-price incentive production contracts with Avondale and Penn for hulls 187-192, 194, and 196;
- Firm fixed-price contracts with Avondale for options on hulls 194 and 196, and with Tampa for completion of hulls 191 and 192;
- Fixed-price incentive with escalation contracts for production of hulls 193 and 195-198; and
- Fixed-price incentive with escalation for production of hulls 199-204.

Table III-23. TAO-187 Henry J. Kaiser Class Program Schedule and Cost Summary

	Development Estimate (12/84)	Current Estimate (12/89)	Current Estimate for Development Estimate Quantity
Development			
Start Date	12/81	12/81	N/A
End Date (IOC)	11/86	2/87	N/A
Quantity	0	0	N/A
Cost	$15.8	$15.3	N/A
Production			
Start Date	11/82	11/82	11/82
End Date	3/94	6/94	6/94
Quantity	17	18	17
Cost	$2,591.9	$2,439.4	$2,381.1
Total Program Cost	$2,607.7	$2,454.7	$2,396.4
Average Unit Cost			
Production	$152.5	$135.5	$140.1
Total Program	$153.4	$136.4	$141.0
Program Status			
Development—Completed			
Production—8 years of data			

Note: N/A means that data were not available, not sufficient, or not applicable. Costs are in millions of base-year 1984 dollars.

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ABBREVIATIONS

AD	advanced development
AIM	ASDAS/ENSCE Interface Module
ASARC	Army Systems Acquisition Review Council
ASAS	All Source Analysis System
AIFV	Armored Infantry Fighting Vehicle
C^2I	command, control and intelligence
CEAC	Cost and Economic Analysis Center (Army)
CFV	Cavalry Fighting Vehicle
COEA	Cost and Operational Effectiveness Analysis
CPI	Communications Processor and Interface
CPIF	cost plus incentive fee
DAB	Defense Acquisition Board
DAIM	Dual ASAS/ENSCE Interface Module
DCG	development cost growth
DCP	development concept paper
DEQ	development estimate quantity
DoD	Department of Defense
DSARC	Defense Systems Acquisition Review Council
DSG	development schedule growth
DTC	design-to-cost
ED	Engineering Development
ENSCE	Enemy Situation Correlation Element
ET/ST	Engineering Test/Service Test
EW	electronic warfare
FAADS	Forward Area Air Defense System
FACC	Ford Aerospace and Communication Corporation
FOG-M	Fiber Optic Guided Missile
FPD	fixed-price development
FSD	full-scale development
FSED	full-scale engineering development
FSIC	Forward Sensor Interface and Control

FVS	Fighting Vehicle System
FY	fiscal year
GDLS	General Dynamics Land Systems
GSRS	general support rocket system
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IDA	Institute for Defense Analyses
IDP	Intelligence Data Processing
IFF	identification, friend or foe
IFV	Infantry Fighting Vehicle
IOC	initial operational capability
ITAWDS	Integrated Tactical Amphibious Warfare Data System
JPL	Jet Propulsion Laboratory
JTFPO	Joint Tactical Fusion Program Office
LAMPS	Light Airborne Multi-Purpose System
LCC	Limited Capability Configuration
LOS-F	line-of-sight forward
LOS-R	line-of-sight rear
LRP	low-rate production
MBT	main battle tank
MENS	Mission Element Needs Statement
MICV	Mechanized Infantry Combat Vehicle
MLRS	Multiple-Launch Rocket System
MOU	memorandum of understanding
MTACCS	Marine Tactical Amphibious Command and Control System
MYP	multi-year procurement
N-LOS	non-line-of-sight
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, and chemical
NDI	non-developmental item
OSD	Office of the Secretary of Defense
P^3I	pre-planned product improvement
PAWS	Portable ASAS/ENSCE Workstations
PCG	production cost growth
PSG	production schedule growth
PVT	Production Validation Testing
RAM-D	reliability, availability, maintainability and durability

RDT&E	research, development, test and evaluation
RFP	request for proposals
ROC	required operational capability
SAR	Selected Acquisition Report
SHORADS	Short-Range Air Defense System
SIGINT	signal intelligence
SURTASS	Surveillance Towed Array Sound System
SVML	Standard Vehicle Mounted Launcher
TOW	tube-launched, optically-tracked, wire-guided
TPCG	total program cost growth
TTF&T	Technology Transfer, Fabrication and Test